PHYSICS 20

Module 1

Describing How Things Move

Physics 20

Module 1

Describing How Things Move

Alberta
EDUCATION

Distance
Learning

This document is intended for	
Students	✓
Teachers (Physics 20)	✓
Administrators	
Parents	
General Public	
Other	

Physics 20
Student Module
Module 1
Describing How Things Move
Alberta Distance Learning Centre
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Welcome to Physics 20!

We hope you'll find this course interesting.

To make your learning a bit easier, many different resources will be presented throughout the course. Some of these resources, such as your textbook, videocassettes, and laser videodiscs, will be flagged with the following icons:
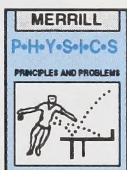
When you see these icons, follow the instructions in your module booklet and go to the appropriate resource.

One important resource that you'll be using all the time is your notebook.

There are no response lines to write on in many of the questions asked in the Student Module Booklet of this course. This means that you will need to have lined paper handy at all times on which to answer the questions. It's probably a good idea if you keep your answer pages in a notebook or binder so that they do not get lost and they are easier to refer to when reviewing or studying. Read all the questions carefully and answer them as completely as possible. Then check your answers in the Appendix.
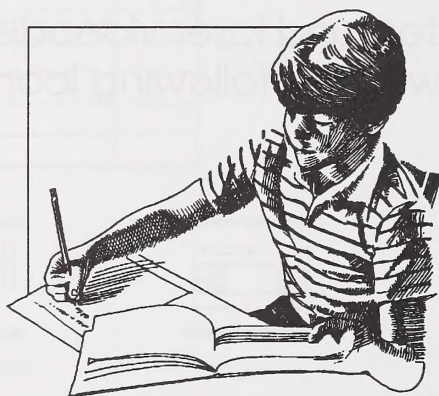
It is also important that you work through the module activities thoroughly before attempting the questions in the Assignment Booklet. This will help you to achieve a greater degree of success in your studies.

Good Luck!

Course Overview

This course contains eight modules. The first four modules involve the study of motion on Earth and in the heavens. Modules 5, 6, and 7 investigate the properties and characteristics of waves in general and light waves. The last module is an introduction to nuclear physics from the point of view of risk/benefit analysis. The module you are working in is highlighted in darker colour.

Module 2

Explaining Why Things Move

Module 3

Curved Motion and Gravitation

Module 1

Describing How Things Move

Module 4

Energy for Motion

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Module 8

Physics for Life: Assessing Risks and Benefits

Module 5

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Module 7

Applications of Light

Module 6

Light as a Wave

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OVERVIEW

"I'm not sure that I really want to do this!" you say to yourself as you look over the edge of the highest water slide that you have ever been on. Unlike the othe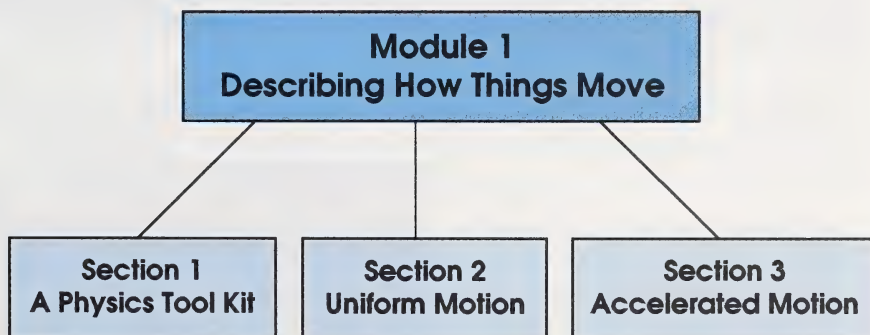rs, this slide is a single drop of almost seven storeys that plunges you into a pool of water. Despite the butterflies in your stomach and the deep pounding in your chest, you go for it. The nearly straight drop seems to last only a heartbeat, and, before you know it, you shoot into the pool like a human torpedo.

When you emerge from the pool, your friends are cheering and laughing at the expression on your face. They all want to know the same thing – "What was it like?"

What words would you use to describe your ride? Would you be able to describe how your body moved? If you watched your friends go down the slide, would you be able to tell them about their motion in words that they would understand?

The focus of this module is to develop the terminology and techniques for describing how things move. You will begin by tuning up your mathematical skills. Then you will investigate the motion of objects with constant speeds and objects with changing speeds. The skills and concepts that you learn in this module will be used extensively throughout the entire course.

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Evaluation

Your mark in this module will be determined by your work in the
Assignment Booklet. You must complete all assignments. In this module
you are expected to complete three section assignments. The mark
distribution is as follows:

Section 1 Assignment	25 marks
Section 2 Assignment	40 marks
Section 3 Assignment	35 marks
TOTAL	**100 marks**

Science Skills

One of the exciting features of this course is that you will develop and
improve your ability in the area of science skills. These skills include the
following:

- initiating and planning
- collecting and recording
- organizing and communicating
- analysing
- connecting, synthesizing, and integrating
- evaluating the process or outcomes

Although these skills are referred to as science skills, it is important to
remember two key ideas.

First, these skills are not just for science. Any time that you solve a problem
or make a decision, some combination of these skills is used.

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Therefore, the skills that you will develop in this course will be very useful for life-long learning. Nearly every activity of your life will require you to solve a problem or make a decision. Some people would even argue that the skills are more important than the particular topics that you study.

Secondly, you will be free to use these skills in a variety of ways. It would be wrong to assume that every scientist uses these skills in the same way to solve every problem. Science is very much a human activity, which means individuality and creativity play a large role.

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The society that the person lives in, the technology that is available, and the very personality of the scientist will determine which skills are combined to create a solution to a problem.

The science that you do and the science skills that you prefer to use will be unique to you. Also, you likely will not be performing at the same level for all skills. In this course you will continually practise all of these skills and you will have an opportunity to assess your level of performance in each skill.

These science skills will be developed further in Activity 1 of Section 1 and explained in detail in the Appendix.

1

A Physics Tool Kit

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When Jill's parents asked her what she wanted for her birthday, they were surprised by her answer.

"I want to redecorate my bedroom – by myself. You can supply the money for the paint and wallpaper and I'll do the rest!"

If Jill asked you to help her with the project, where would you start? One of the first things that you would have to do is solve the problem of achieving the new look with the small budget that is provided. Then you would have to measure the room, calculate the area of the walls, and determine how much material you need. Since the budget is restricted, you would have to measure and calculate very carefully. Finally, you would have the fun of carrying out the plan by redoing the room!

The skills of problem solving, measuring, performing calculations, and manipulating tools are also an important part of physics. In this section you will examine the techniques that physicists often use to solve their problems. You will also review the use of your calculator and the mathematical skills that are used for working with measurements. At the end of this section you should have a good physics tool kit to take with you through the whole course.

Activity 1: Physics and the Scientific Method
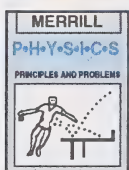
Physics is a mathematical science. This fact affects how physicists go about solving problems, creating experiments, and proposing theories.

If you think of the universe as a huge machine, physics is the study of what makes it work and how it operates. The scientific skills and processes that you have studied up to this point are useful in this field. As an example of this, your textbook tells the story of "high temperature" **superconductors**.

Read pages 2 to 8 in your textbook. Then do the following questions.

1. Fill in the boxes in this time line. This will put the story into a chronological framework.

2. Do Concept Review question 1.1 on page 9 of your textbook.

3. In this case, the theory came after the discovery of the **phenomenon**. How much later? Why did it take so long? Give your opinion.

4. There was a flurry of work done in 1986 and 1987. Why? Give your opinion.

5. There are many applications of superconductors. Name two that are mentioned in the textbook.

One reason that the high temperature superconductor field is a good beginning for an introduction to physics is that it still is not finished. The University of Alberta in Edmonton is strong in research in this field. New theories of superconductivity and new storage methods for low temperature substances are being developed as you read this.

The following diagram of the thermometer shows some important information that relates to superconductivity. Note that the temperatures are given in the **Kelvin temperature scale** and degrees Celsius.

Kelvin temperature scale – a scale that begins at absolute zero and goes up, with each Kelvin the same size as one Celsius degree

22°C   295 K Room temperature
0°C   273 K Water freezes

-78°C   195 K CO_2 freezes (dry ice)

            98 K Ceramic substance
-183°C   90 K Oxygen liquefies   superconducts
-196°C   77 K Nitrogen liquefies

            23 K Niobium germanium,
            4 K Helium liquefies   niobium titanium
-273°C   0 K Absolute zero   alloys superconduct
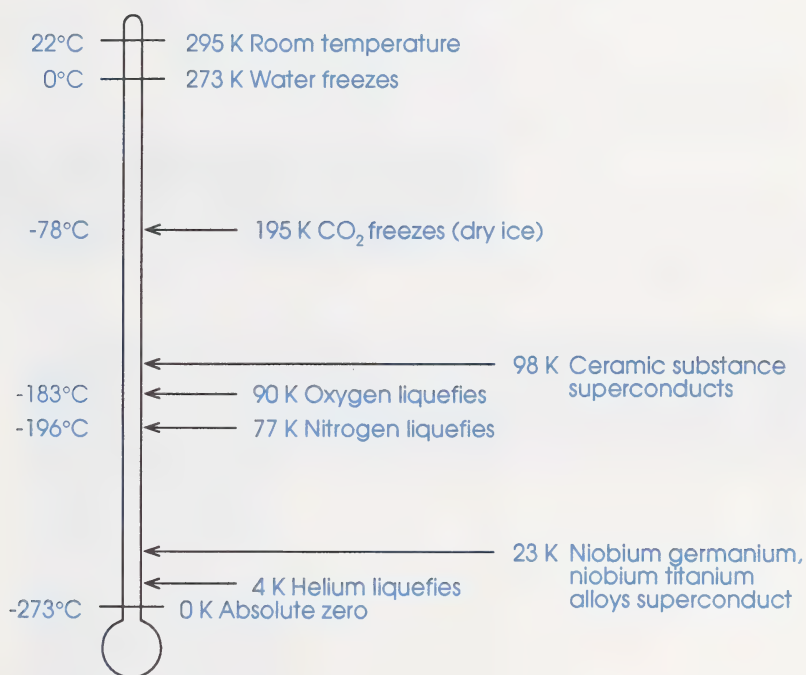
6. Superconductivity only occurs below some critical temperature for each substance. Mercury superconducts below 4.2 K. Can liquid nitrogen be used to make mercury superconduct? Why or why not?

7. The ceramic superconductors were thought to be really important because they superconduct above 77 K. Why is this so important?

The ceramics proved to be a disappointment. They get brittle at low temperatures and they are extremely hard to make into wires for motors and electromagnets. The lower temperature metal alloys are easier to work with, but need liquid helium to make them work.

Look at Applying Concepts question 10 on page 11 of your textbook. What do you think the answer is? The answer is that they both do! The advance of science is a creative thing. The scientific method doesn't always move from point A to point B.

Read the last paragraph and the margin notes on page 9 of your textbook and answer the following question.

8. At the beginning of this module you were introduced to process skills. Compare the process skills to the scientific methods given on page 9 of your textbook.

Comparing the Process Skills Model to the Methods of Scientists	
Similarities	Differences

Check your answers by turning to the Appendix, Section 1: Activity 1.

As you complete this course you will be continually practising the skills of science. You will be asked to assess your ability and you will receive feedback on your progress. The whole purpose of this is so that you can improve and grow in your abilities.

Although many schemes are possible, in this course the science skills are identified by the following six categories:

- initiating and planning
- collecting and recording
- organizing and communicating
- analysing
- connecting, synthesizing, and integrating
- evaluating the process or outcomes

A detailed description of each skill can be found at the beginning of the Appendix. Turn to the Appendix and read A Framework for Scientific Problem-solving Skills to familiarize yourself with what each skill means.

9. Recall the story of Jill's redecorating project in the introduction to this section. Use the description of each science skill in the Appendix to help give an example of each skill as it would apply to Jill's project. Place your answers in the chart that follows here and on the next page.

Illustrating Science Skills in a Redecorating Project	
Science Skill	**An Example of the Skill from Jill's Project**
Initiating and Planning	
Collecting and Recording	
Organizing and Communicating	

Science Skill	An Example of the Skill from Jill's Project
Analysing	
Connecting, Synthesizing, and Integrating	
Evaluating the Process or Outcomes	

Check your answers by turning to the Appendix, Section 1: Activity 1.

The method used to assess your ability in each of these skills involves using a level of performance. There are five possible levels. Level 5 is the top level of performance. It describes work that would be done at a college or university calibre. Since you are a high school student, it is reasonable to assume that you will likely be operating at levels 2, 3, or 4 in most of the skills. It is normal to be performing at different levels for some of the science skills.

To familiarize yourself with the differences between each of these levels, read the descriptions for each level as they are applied to each of the six science skills. The descriptions can be found in the Appendix. Then do the questions that follow.

10. Pierre and Scott are each given the task of determining the height of the gymnasium's ceiling. The students are told to answer to the nearest centimetre. Both students are told that they will be assessed on the following skills:

   - initiating and planning
   - collecting and recording

The boys hand in the following reports:

Height of the Gymnasium Ceiling

by Pierre

Initiating:

   To determine the height, I decided to consult an expert. I thought that the best thing to do was to look up the answer on the school's blueprint. Mr. Gomez, the Head Custodian, keeps these plans in his office, so I went to see him.

Collecting and Recording:

   Mr. Gomez let me look at the blueprint, but it was only a floor plan. The part of the plan with heights was missing (The basketball coach took it for the installation of new backboards.). Mr. Gomez told me that the ceiling was about 8 m high. He must know!

So, the gymnasium's ceiling is about 8 m high.

My Plan to Measure Height

Initiating:

To solve this problem I decided to count the cement blocks up the gym wall. I counted 39 blocks.

Then I carefully measured one block. It was exactly 19.7 cm high.

So, the height of the gymnasium's ceiling can be calculated as follows:

$$39 \times (19.7 \text{ cm}) = 768 \text{ cm}$$

The gymnasium's ceiling is 768 cm high.

Scott

---

a. At what level would you assess Scott and Pierre's reports in terms of initiating and planning? Explain your answers by referring to the information in the Appendix.

Level of Initiating and Planning	
Pierre	Scott

b. At what level would you assess Scott and Pierre's reports in terms of collecting and organizing? Explain your answers by referring to the descriptions in the Appendix.

Level of Collecting and Recording	
Pierre	Scott

Pierre and Scott, like everyone else, can improve their abilities with these skills. Their levels of performance should not be interpreted as a grade, but rather as valuable feedback to help them begin to realize what they need to do to improve. The important thing here is not the level itself, but how much they can improve and grow in each skill category.

To help you improve and grow in your abilities with these skills, a strategy has been developed for this course.

Practice

Whenever an opportunity to practise one of the science skills arises, you will see an icon like the one shown in the left margin. Note that the names of the skills have been shortened to one word. The skills that you will be practising will be checked off within the icon. If you were doing the same task as Pierre and Scott, you would see the first two skills checked off in the icon.

Self-assessment and Teacher Assessment

Some of the questions in your Assignment Booklet will allow you to use a skill. You will be asked to assess your level of performance after you have answered the question. You will record your self-assessment in an icon like the one shown below. Record your self-assessment in the first columns of boxes.

Science Skills

- ☑ A. Initiating
- ☑ B. Collecting
- ☐ C. Organizing
- ☐ D. Analysing
- ☐ E. Synthesizing
- ☐ F. Evaluating

Evaluate your skill level in the appropriate self-assessment boxes according to the science skills framework.

	Self	Teacher		Self	Teacher		Self	Teacher
A. Initiating	4		B. Collecting	3		C. Organizing		
D. Analysing			E. Synthesizing			F. Evaluating		

In this case, you would have assessed yourself as performing at level 4 in initiating and level 3 in collecting.

Your Assignment Booklet is evaluated by a teacher. When grading a question that involves science skills, the teacher will assess your ability and record what is believed to be your level of performance. This will be recorded in the same icon as your self-assessment. Note that the skill level indicated by the teacher is **not** reflected in the mark of the question. The purpose of the skill assessment is to encourage you to grow in your abilities.

Evaluate your skill level in the appropriate self-assessment boxes according to the science skills framework.

	Self	Teacher			Self	Teacher			Self	Teacher
A. Initiating	4	3	B. Collecting	3	3	C. Organizing		
D. Analysing			E. Synthesizing			F. Evaluating		

In this case, the teacher assessed you to be at level 3 in the skill of initiating and planning and at level 3 in the skill of collecting and recording. Note that the self-assessment agreed with the teacher assessment in ability to collect information, but differed in terms of the assessment for initiating and planning.

11.   Why is it worthwhile for you to assess your own work in your Assignment Booklet?

Charting Growth

The whole purpose of identifying science skills with these icons is to encourage your development and growth in each of the science skills. In the examples given, collecting and initiating were assessed. The self-assessment and the teacher assessment both showed collecting to be at level 3; therefore both agree that improvement is necessary. The self-assessment showed initiating to be at level 4, while the teacher assessment showed initiating to be at level 3. In this case, your initiating skills are not as developed as you had thought. Improvement is needed.

This feedback from the assessments is valuable and needs to be charted over time. As you progress through the course, you will be practising the same skills throughout each module. To keep track of this growth, record **both** the self-assessment and the teacher assessment on the spreadsheet found in the Module 8 Assignment Booklet.

Assignment
Booklet

12. Turn to your Module 8 Assignment Booklet and find the spreadsheet for recording the assessment of process skills.

   a. When you get your assignments back, what two assessments do you record on the spreadsheet?

   b. What is the advantage of recording all the assessments from the whole course on one spreadsheet?

   c. Why is the spreadsheet located in the Module 8 Assignment Booklet?

Check your answers by turning to the Appendix, Section 1: Activity 1.

Activity 2: Test Your Readiness I

The math that is used in high school physics is not that hard. You do, however, need to know how your calculator handles things like arithmetic, squares and square roots, trigonometric functions, and scientific notation. You must also be familiar with the SI metric system, its units, and how to convert from one unit to another.

Try the following pretest. If you score well, you do not need to study these topics and you may go on to the next item.

Pretest on Calculator Arithmetic

Use a calculator to determine the answer to each of the questions.

1. $4 + 4 + 4 \div 4$

2. $\dfrac{36}{9 + 9}$

3. $\dfrac{24 \times 32 \times 100}{48 \times 160 \times 10}$

4. $\sqrt{\dfrac{68.0 \times 41.0}{43.5625}}$

5. $\sqrt[3]{3.375}$

6. $4.0 \times 16.88 + \dfrac{1}{2} \times 13.6^2$

7. $2\dfrac{1}{2} \times \dfrac{6}{11}$ (Express this answer as an improper fraction.)

8. $\sin 43°$

9. $\cos 71°$

10. $\tan 80°$

11. $399 \sin 70°$ (Express this answer to the nearest whole number.)

12. 88.6% of 500

13. $\dfrac{2.611 \times 10^5}{3.5 \times 10^8}$

14. $\left(3.466 \times 10^6\right) + \left(2.84 \times 10^5\right)$

15. $\dfrac{\left(4.0 \times 10^6\right)\left(9.8 \times 10^6\right)}{5.6 \times 10^3}$

16. $\sqrt{\dfrac{5.6 \times 10^{-10}}{1.4 \times 10^{-22}}}$

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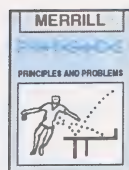
Check your answers by following the clues in the chart. Just for fun, you will use this chart to help you get familiar with your textbook. All the page references listed are from your textbook.

Solutions to Pretest Questions		
Pretest Question	**Where to Find the Answer**	
	Textbook Page Number	**Clue**
1	9	number of people on the Houston research team
2	196	number of cyclists
3	366	number of magnifying glasses
4	441	number of capacitors
5	62	time to fall in the "Demon Drop" (seconds)
6	469	total wattage of the bulbs
7	39	ratio of $\dfrac{\text{slices of pepperoni on large pizza}}{\text{slices of pepperoni on small pizza}}$
8, 9, 10	714	Check the trig table. (These numbers are rounded off to four decimal places.)
11	15	millilitres of pop in the can
12	117	height of the Sears Tower in Chicago (in metres)
13	509	output of the world's smallest motor (in watts)
14	409	energy of a single lightning bolt (in joules)
15	7	cost of the new Superconducting Super Collider in Texas (dollars)
16	425	ultra high voltage (in volts)

How did you score on the pretest of calculator arithmetic? If you got less than 13 correct answers, you need to carefully complete the following review. If your score was 13 or more, skip ahead to the pretest on the SI metric system.

Review of Calculator Arithmetic

Each calculator is different. If you want success with yours, here are some tips:

- Don't throw out the manual!

- Estimate the answers before you start calculating.

- Know the order of operations. How does your calculator handle these?

- Be sure your calculator is set in degrees (not gradients or radians), especially after lending or borrowing a calculator.

- In scientific notation $\boxed{\text{EE}}$ or $\boxed{\text{EXP}}$ means "times 10 to the power of". If you enter $\boxed{2}\boxed{\text{EXP}}\boxed{3}$, it means 2×10^3 or 2000. A common error is to attempt to enter 2×10^3 by pressing $\boxed{2}\boxed{\text{x}}\boxed{1}\boxed{0}\boxed{\text{EXP}}\boxed{3}$, which is actually 20×10^3 or 20 000.

Use these suggestions and re-attempt the questions that you got wrong in the pretest. Answers may be double-checked in the Appendix.

order of operations – Some people remember the order of operations by memorizing BEDMAS.

- Brackets
- Exponents
- Division and Multiplication
- Addition and Subtraction

Pretest on SI Metric Units

When you solve problems in physics, it is very important to use the proper units. Attempt the following questions to determine how ready you are to complete calculations involving metric units.

17. Give the standard unit for each of the following quantities.

Quantity Measured	Standard Unit
length	
mass	
time	
speed	

18. Convert the given measurement to the appropriate unit.

a. 17 000 m = _____ km

b. 2.54 cm = _____ m

c. 4.6 g = _____ kg

d. 19.6×10^5 kg = _____ t

e. one day = _____ s

f. 9000 s = _____ h

g. 615 nm = _____ m

h. 405 μm = _____ m

i. 12.0 MHz = _____ Hz (Hz = hertz = cycle per second)

j. 22.8 GJ = _____ J (J = joule = energy units)

19. a. $1.05 \text{ m} + 5 \text{ cm} = $ _____ m

   b. $600 \text{ g} + 1.5 \text{ kg} - 400 \text{ g} = $ _____ g

   c. $2.5 \text{ cm} \times 3.6 \text{ cm} \times 9.1 \text{ cm} = $ _____ (include unit)

   d. $100 \text{ m}^3 \div 6.25 \text{ m} = $ _____ (include unit)

   e. $2.5 \text{ cm} \times 1.1 \text{ cm} + 0.50 \text{ cm} \times 3.6 \text{ cm} = $ _____ (include unit)

Check your answers by turning to the Appedix, Section 1: Activity 2.

Answer Key

Use the following charts to check your answers to questions 18 and 19. Find the answer for each question and put the corresponding code letter in the appropriate blank. Question 18. a. has been done as an example.

Answers to Question 18	Code Letter
2.5	R
2.28×10^{10}	T
0.0254	L
4.05×10^{-4}	E
1960	C
1.20×10^{7}	C
17	A
4.6×10^{-3}	L
86 400	O
6.15×10^{-7}	R

The answer to 18. a. is 17. So the code letter A goes here!

A __ __ __ __ __ __ __ __ __ !
a. b. c. d. e. f. g. h. i. j.

Answers to Question 19	Code Letter
1700	U
$16.0 \, m^2$	E
$1.10 \, m$	S
$4.55 \, cm^2$	R
$81.9 \, cm^3$	P

___ ___ ___ ___ ___ !
a. b. c. d. e.

Were you able to decode the messages? If you got less than 16 correct answers, you need to complete the following review. If your score was 16 or more, skip ahead to Section 1: Activity 3.

Review of SI Metric Units

The metric system exists in several forms. Different countries have different customs of which units to use. SI metric is the standard version of the metric system used by scientists worldwide.

Converting metric units usually involves a power of 10 (a shifting of a decimal place) only. Be careful though – any unit involving a time change will involve more than a simple decimal change! Time works on a base 60 number system, not a base 10 number system.

20. Look in your textbook. Read pages 14 and 15 and complete Practice Problems 1, 2, and 3 on page 16.

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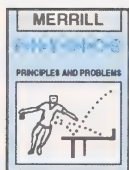
Check your answers by turning to page 656 in your textbook.

When changing from one metric unit to another, you will either divide or multiply by a power of 10.

BIG UNIT	➡	small unit

- multiply
- decimal moves right

small unit	➡	BIG UNIT

- divide
- decimal moves left

Why does this logic work?

21. Consider a person with big steps and one with small steps. They both pace off the same distance. Who takes more steps? Why?

Time is a problem. Since 60 s equals 1 min, divide by 60 to change seconds to minutes. To change minutes to hours, divide by 60 again.

$$\text{seconds} \underset{\times 60}{\overset{\div 60}{\rightleftarrows}} \text{minutes} \underset{\times 60}{\overset{\div 60}{\rightleftarrows}} \text{hours}$$
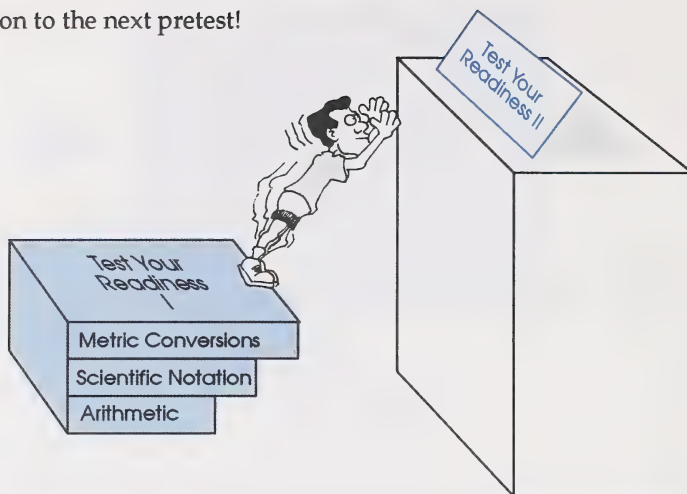
22. How many seconds are there in an hour?

Check your answers by turning to the Appendix, Section 1: Activity 2.

23. Look at the Example Problems on pages 17 to 19 in your textbook. Then do Practice Problems 4, 6, 8, and 10 on these pages.

Check your answers by turning to page 656 in your textbook.

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Now, on to the next pretest!

Activity 3: Test Your Readiness II

All measurements are accurate to a certain level only. That means that it is important for you to know how to round off answers correctly. Physicists do a lot of graph work, so you will need to know how to make, read, and interpret graphs. The ability to manipulate **algebraic** equations is important for physics, too. Later on in this section you will review how to manipulate equations.

algebra – mathematics where letters take the place of numbers

How Certain Are Your Measurements?

Perform these calculations and round your answers to the correct number of decimal places.

1.   6.23 cm + 18.6 cm

2.   0.0651 kg + 10.02 kg + 3.033 kg

3.   48.116 cm
         188.01   cm
      + 496   cm
      _____

4.   387.9   kg
      – 116.81 kg
      _____

Do these questions and round to the correct number of significant digits.

5. $2.36 \text{ cm} \times 1.2 \text{ cm}$

6. $9.81 \text{ m/s} + 2.852 \text{ m/s}$

7. $13.6 \text{ kg} + 118.22 \text{ kg}$

8. $1.1 \text{ cm} \times 2.3 \text{ cm} + 6.8 \text{ cm} \times 11.55 \text{ cm}$

9.   Define the term *precision*.

10.   Define the term *accuracy*.

To check your answers, match the number of the question on the left to the answer on the right by connecting the dots with a straight line. Be sure to use a ruler.

Question Number   **Answer**

1 •   • 3.44

2 •   ⓞ   • 13.12 kg
              ①
3 •   ⓨ   • closeness to correct

4 • ⓤ   ⓖ   • 24.8 cm

5 •   ⓕ   ⓡ   • 0.115

6 • ⓔ   • 81 cm^2

7 •   ⓡ   • number of decimal places

8 • ⓔ   • 271.1 kg
         ⓐ   ⓢ
9 • ⓣ   ⓗ   • 2.8 cm^2

10 •   • 732 cm

Notice that the straight line from each question number passes through a letter. Record the letter for each question to decode the message.

$$\underline{}\ \underline{}\overset{\prime}{}\ \underline{}\ \underline{}\ \underline{}\ \underline{}\ \underline{}\ \underline{}\ \underline{}\ \underline{}\ !$$
$$\ \ 1\ \ 2\ \ 3\ \ 4\ \ 5\ \ 6\ \ 7\ \ 8\ \ 9\ \ 10$$

Were you able to decode the message? If you had less than 8 correct answers, you need to complete the review of measurements. If you got 8 or more correct, you may skip ahead to the section on graphing.

Review of Measurements

No measurement is exact. Even if an instrument was capable of exact measurement, it would not work to that level.
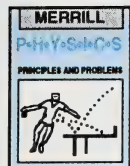
Suppose you wanted to know the exact length of a stick. Imagine that you could zoom in closer and closer to see the end of the stick. Suddenly you would see a group of atoms like the ones shown.
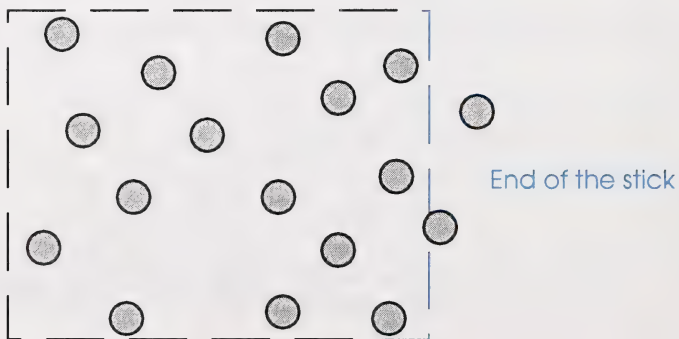
End of the stick

Which atom is exactly at the end of the stick? Do you measure to the centre of the atom or its edge? It's moving too! If you look closer and zoom into one atom, you will see that it is changing and moving! Are you seeing where the atom actually is?

Read pages 21 and 22 of your textbook. Pay particular attention to the meaning of precision and accuracy. Then try the following question.
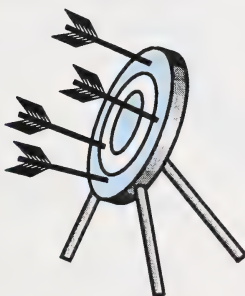
11. Here are some targets that have been shot at. Each one represents a combination of good or bad accuracy and precision. Match the descriptions with the letters of the targets.
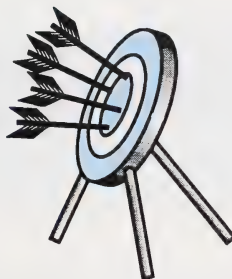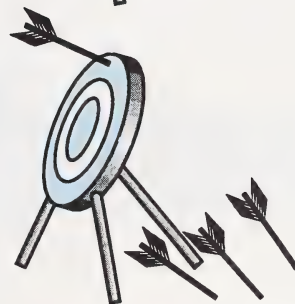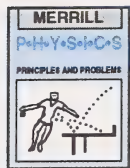
a.

b.

c.

d.

good accuracy, good precision _____
good accuracy, bad precision _____
bad accuracy, good precision _____
bad accuracy, bad precision _____

precision – how many decimal places a measure has been taken to

accuracy – how close a measure is to the correct value

Check your answers by turning to the Appendix, Section 1: Activity 3.

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12. Read the section on significant digits on pages 22 and 23 of the textbook. Try Practice Problems 12 and 13 on page 24.

Check your answers by turning to page 657 in your textbook.

13. Three groups of people agreed to work together to measure a building. Each group measured part of the building and then they pooled their results to develop a common blueprint for the building.

- Group 1 measured very precisely to the nearest millimetre.
- Group 2 measured to the nearest centimetre.
- Group 3 rounded their measurements to the nearest metre.

Which of the following statements is most correct for this situation?

Statement 1: Since Group 1 measured to the nearest millimetre, the plans can be drawn to this precision.

Statement 2: Since Group 3 did such a poor job, the plans can only be drawn to the nearest metre.

Check your answers by turning to the Appendix, Section 1: Activity 3.

Here is a tip to help get the correct number of significant digits in your answers.

The first significant digit of any measurement cannot be a zero!

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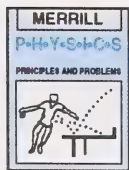
Look at the Example Problems on pages 24 and 25 of your textbook. This is the crucial part of this topic. It is here that you learn just where to round off your numbers.

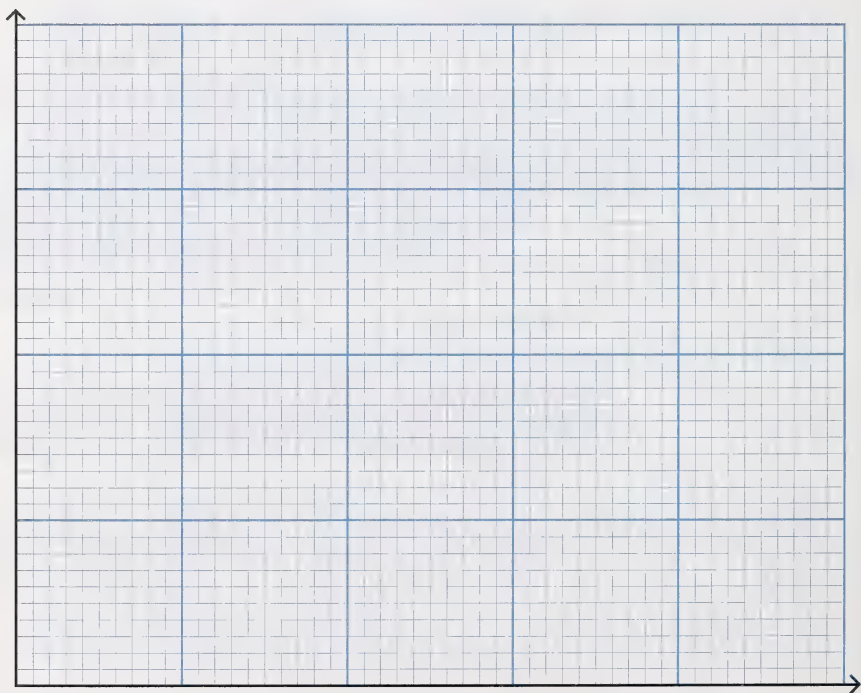14. Now try questions 14 to 17 on pages 25 and 26 of your textbook to see if you have mastered the concept.
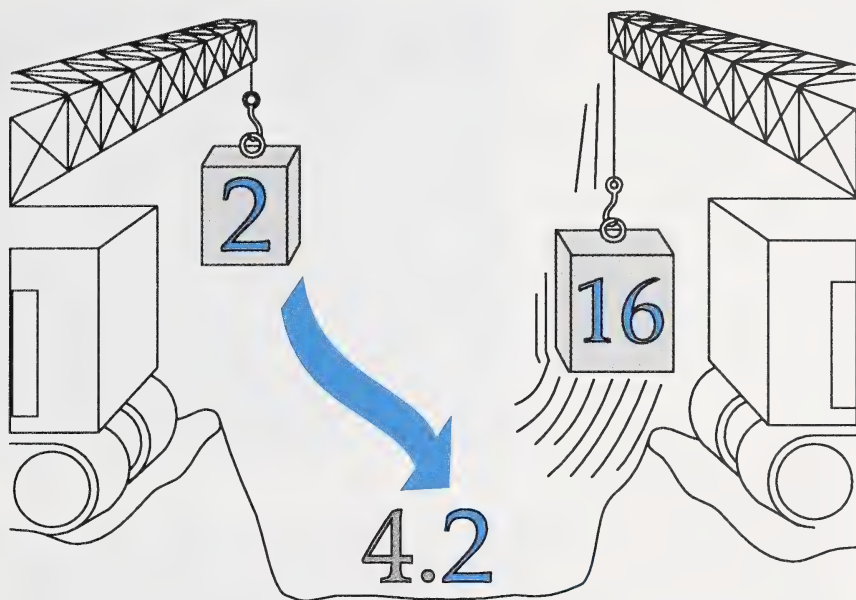
Check your answers by turning to page 657 in your textbook.
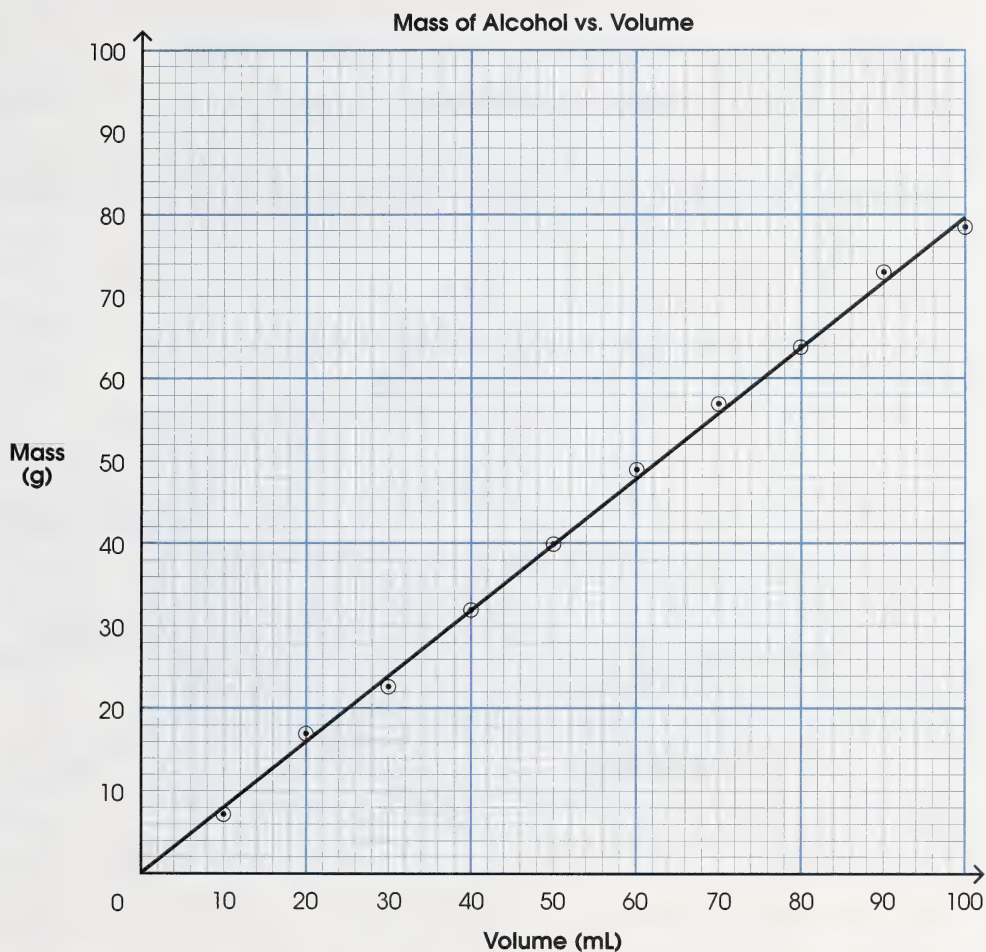
Graphing

In addition to using your calculator, knowing the SI metric system, and understanding the rules for rounding off measurements, graphing is also an important tool used in physics. To test your graphing skills, do the next questions.

15. Draw a graph of the information provided in the following chart. Be
    sure to follow the rules for graphing and remember to draw the best fit
    line.

Manipulated Variable: Depth Under Water (m)	Responding Variable: Pressure (atmospheres)
0 (surface)	1.0
5.0	1.5
10.0	1.9
15.0	2.4
20.0	2.9
25.0	3.5

16. Look at this graph and answer the questions that follow.


Mass of Alcohol vs. Volume

a. What is the slope of the graph? Include the correct units.

b. What does the slope represent?

c. What type of relationship exists between the mass and volume of alcohol?

Check your answers by turning to the Appendix, Section 1: Activity 3.

Check your answers to questions 15 and 16. a. in the Appendix. If you got both of these questions completely correct, you may skip ahead to Manipulating Algebraic Equations. If you had errors in questions 15 or 16. a., you need to complete the review of graphing.

Review of Graphing

Graphs are extremely important in physics. The following example shows the rules of graphing. Carefully look at this graph and read the rules that follow.
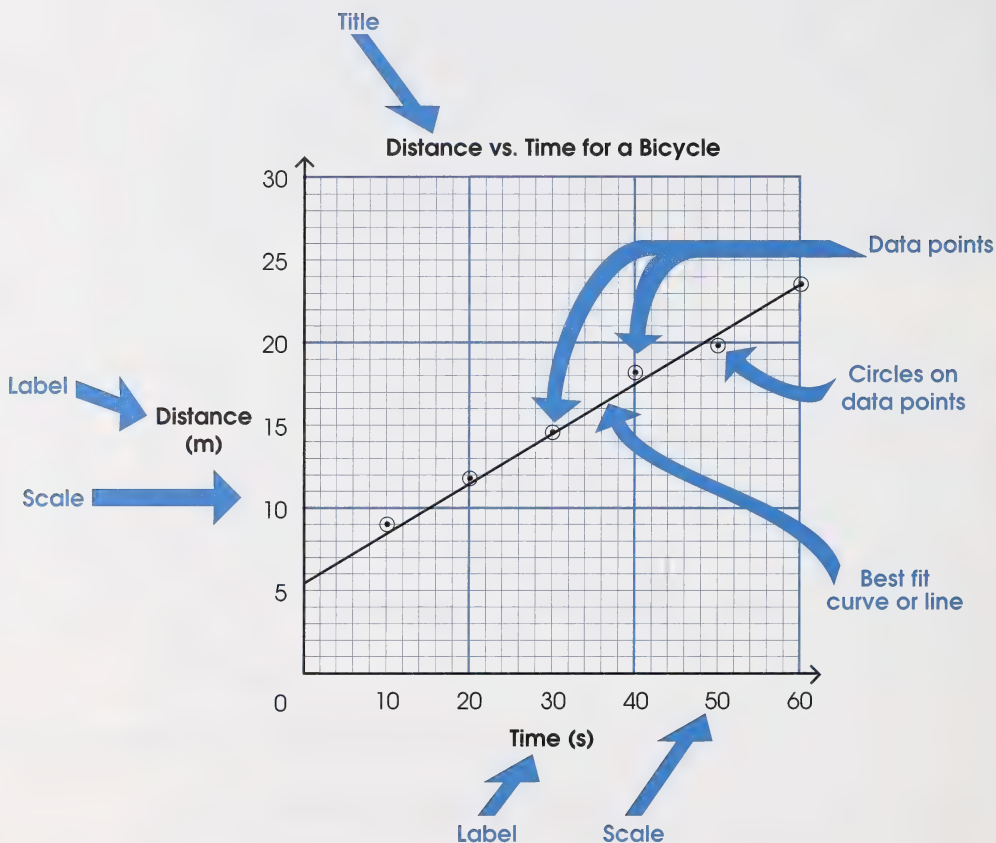
Title

- Every graph must have a title.

- The title is usually a statement of the responding variable versus the manipulated variable.

- You may add other information to the title if necessary.

Labelling the Axes

manipulated variable – the variable that you change

- The manipulated (independent) variable is usually placed on the horizontal or x-axis.

responding variable – the variable that changes as a result of the manipulated variable

- The responding (dependent) variable is usually placed on the vertical or y-axis.

- The labels must include what is being measured and the correct units for those measurements.

Scales

controlled variable – the variable that is held constant in an experiment

- Choose a scale that makes the graph as large as possible on your page.

- Pick a scale that is easy to read. (Don't count by 37s to get a large graph!)

Data Points

- Data points should be placed as accurately as possible on the graph paper.

Circles on Data Points

- Circles are used to indicate uncertainties in measurements and to keep the points from disappearing when the line is drawn.

- Their sizes can be calculated by analysing the errors in an experiment.

Best Fit Curve or Line

best fit curve – the curve (or line) that tracks the general trend of some data on a graph

- Data points do not usually line up perfectly due to experimental errors.

- Draw the line or curve that comes as close as possible to as many points as possible.

- If the trend is a straight line, use a ruler to draw it.

- Do not just connect the dots.

17. Look at the graph at the top of page 30 of your textbook. Mark the graph to see if it follows all the rules. Use the marking key that follows.

	Check
Is the title correct?	
Are the axes correctly labelled? Do the labels include the correct measures and units?	
Are the scales easy to read?	
Are the points accurately placed?	✓
Has the best fit curve or line been drawn?	

Check your answers by turning to the Appendix, Section 1: Activity 3.

The shape of the best fit line or curve shows the mathematical relationship between the variables used.

Linear means "straight". If the best fit curve is a line, mathematically it can be expressed in standard form as shown.

$$y = mx + b$$

slope   y-intercept

direct relationship – This is described mathematically by $y \propto x$. Increases in x cause proportional increases in y.

inverse relationship – This is described mathematically by $y \propto \dfrac{1}{x}$. Increases in x cause proportional decreases in y.

The trick is to interpret what the slope and y-intercept mean for each graph.

A direct relationship produces a graph that is linear (straight) and goes through the origin (the y-intercept is zero). This means that one variable is a multiple of another.

If one variable increases as the other decreases, it is an inverse relationship.
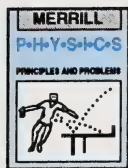
18. Do question 16 on page 38 of your textbook.

Check your answers by turning to the Appendix, Section 1: Activity 3.

Manipulating Algebraic Equations

In previous math courses (and some science courses), you were asked to solve for x. By now you should be able to do this quite easily. Just remember that if you do something to one side of the equation, you must do the same thing to the other side of the equation.

Example

The following equation can be solved with numbers or variables.

You are given the following variables.

$$v_f = 22.8$$
$$v_i = 11.2$$
$$a = 2.5$$
$$t = ?$$

You may ignore units for now!

Using the equation $v_f = v_i + at$, solve for t (the unknown variable).

First solve the equation using numbers.

$$22.8 = 11.2 + 2.5t$$

Subtract 11.2 from both sides.

$$11.6 = 2.5t$$

Divide both sides by 2.5.

$$4.6 = t$$

$t = 4.6$

Now solve the equation using variables.

$$v_f = v_i + at$$

Subtract v_i from both sides.

$$v_f - v_i = at$$

Divide both sides by a.

$$\frac{v_f - v_i}{a} = t$$

$$t = \frac{v_f - v_i}{a}$$

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Look at the Example Problems on pages 32 and 33 of the textbook. The first one can be done a different way than shown in the textbook. You are still solving for x.

$$\frac{ay}{x} = \frac{cb}{s}$$

Cross multiply.

$$ays = cbx$$

Rearrange the equation to bring x to the left side.

$$cbx = ays$$

Divide both sides by cb.

$$x = \frac{ays}{cb}$$

The answer is the same as in the textbook.

19. Now try Practice Problems 18, 19, and 22 on page 33 of your textbook.

Check your answers by turning to page 657 in your textbook.

How did you do at manipulating the equations in Practice Problem 19? Some of the questions were quite challenging. If you correctly rearranged 5 or more, you may continue with the Follow-up Activities. If you got less than 5 correct, you should complete the following review.
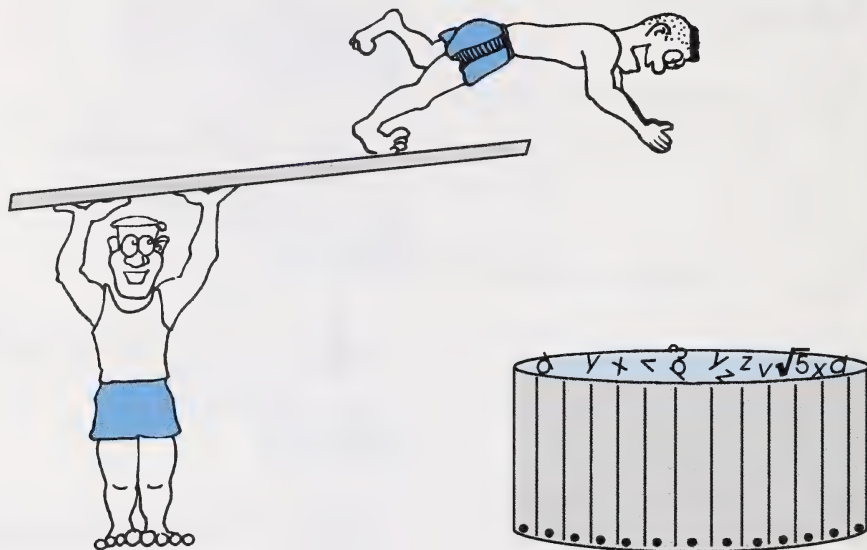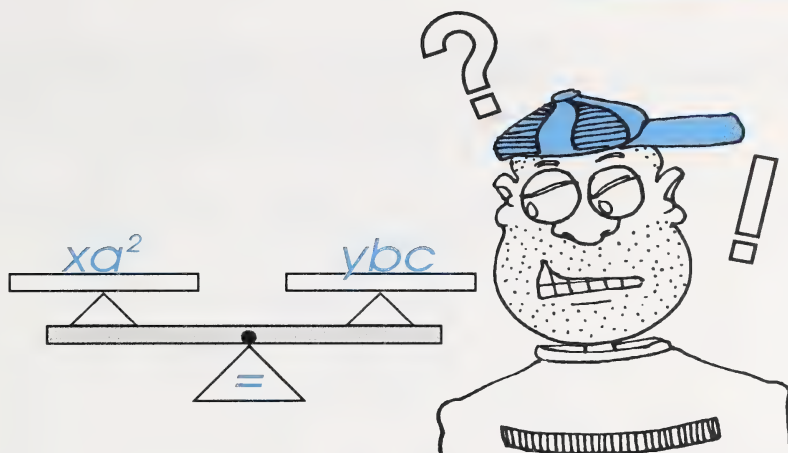

Review of Manipulating Equations

20. Solve each equation for the variable indicated.

a. $i = prt$ Solve for r.

b. $A = \pi r^2$ Solve for π.

c. $V = \pi r^2 h$ Solve for r.

d. $d = v_i t + \frac{1}{2} a t^2$ Solve for a.

e. $v_f = v_i + at$ Solve for t.

Check your answers by turning to the Appendix, Section 1: Activity 3.

Follow-up Activities

If you had difficulties understanding the concepts in the activities, it is recommended that you do the Extra help. If you have a clear understanding of the concepts, it is recommended that you do the Enrichment.

Extra Help

Physics is a science which follows the scientific method of learning things. The story of the high temperature superconductors that you read in Activity 1 is an illustration of one way that this method works.

1. Draw arrows that show the correct order of these scientific processes.

Do an experiment.

State a problem.

Predict an outcome.

Make a theory.
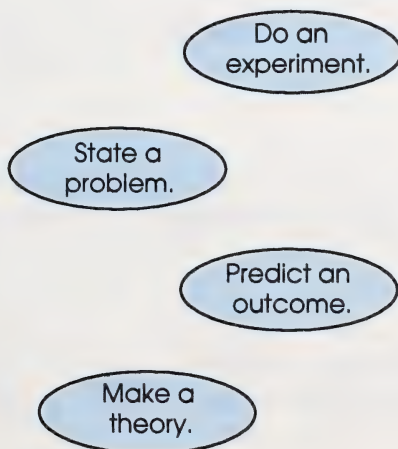
When using a calculator, be careful to estimate your answers and write numbers down as you go. Lots of physics students claim to be no good at physics, even if they know the physics theory well. They make most of their mistakes with the math that is involved.

Learn how your calculator handles scientific notation. Figuring it out now will save time later on.

2. Try these calculations.

a. $\dfrac{(48.1)(36.2)}{111.8}$
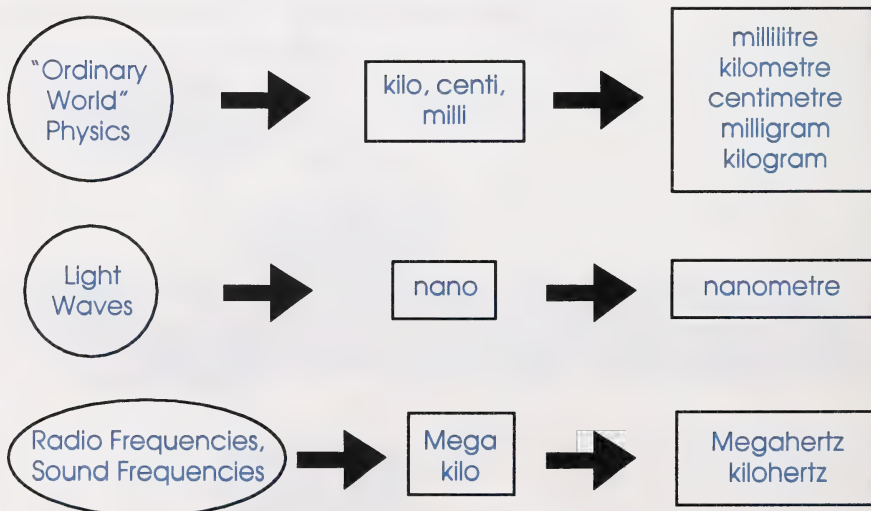
b. $2.5^2 - 1.6^2$

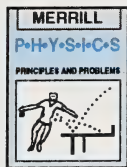c. $\left(1.81 \times 10^6\right)\left(2.62 \times 10^{-7}\right)$

d. $\sqrt{485^2 + 96^2}$

e. $\left(7.05 \times 10^{-5}\right) \div \left(1.6 \times 10^2\right)^2$

f. 681 (sin 45°)

g. $\left(48 \times 16 + 3 \times 87\right)^2$

In physics, not all of the metric prefixes are used on a regular basis. Here are the ones to watch for. Learn these metric prefixes first. The others will come a few at a time.

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3. Put the conversion factors between the prefixes and the base units into the boxes. The first one is done for you. You may refer to Table 2-1 on page 17 of your textbook for help.

    a. one metre   = 10^9 or a billion   nanometres

    b. one gram   =   centigrams

    c. one kilohertz =   hertz

    d. one millimetre =   metres

    e. one hertz   =   Megahertz

Since all measurements have errors and uncertainties in them, you need a set of guidelines to know how to round off answers. Look at the following measurement.

1.35 cm ⬅ Has 3 significant digits.

⬆

Precision is to the nearest 0.01 cm.

When adding or subtracting, perform the calculation and then round off to the least precise measure.

$$2.8|51$$
$$11.9|$$
$$+\ 1.2|8$$
$$\overline{16.0|31}$$

The answer is 16.0. 11.9 is the least precise measure.

When multiplying or dividing, perform the calculation and then round off to the least number of significant digits.

$$2.853$$
$$\times 0.121$$
$$\overline{0.345\ 213}$$

The second measurement has only 3 significant digits. The correct answer is 0.345.

4. Do the following calculations and round off according to the rules. Assume that all numbers shown are measurements.

   a. $1.16 + 2.8001 + 3.92$

   b. $\begin{array}{r} 4.09 \\ -\ 2.116\ 58 \\ \hline \end{array}$

   c. $(0.0190)(11.611\ 802)$

   d. $\left(4.95 \times 10^{-11}\right)\left(1.60 \times 10^{33}\right)$

   e. $48.0 \div 16.118$

5. Use the rules for graphing to check the following graph. The graphed information is provided for you in a chart.

   a.   Find the errors on the graph and correct each mistake right on the graph.

   b.   Is this graph a linear one?

   c.   Is it a direct relationship?

   d.   What does the slope represent?

   e.   What is the value of the slope? Be sure to include the correct units in your answer.

Manipulated Variable: Temperature (°C)	Responding Variable: Length of Wire (cm)
0	11.0
10	11.4
30	12.3
50	13.1

Length
of wire

Temperature
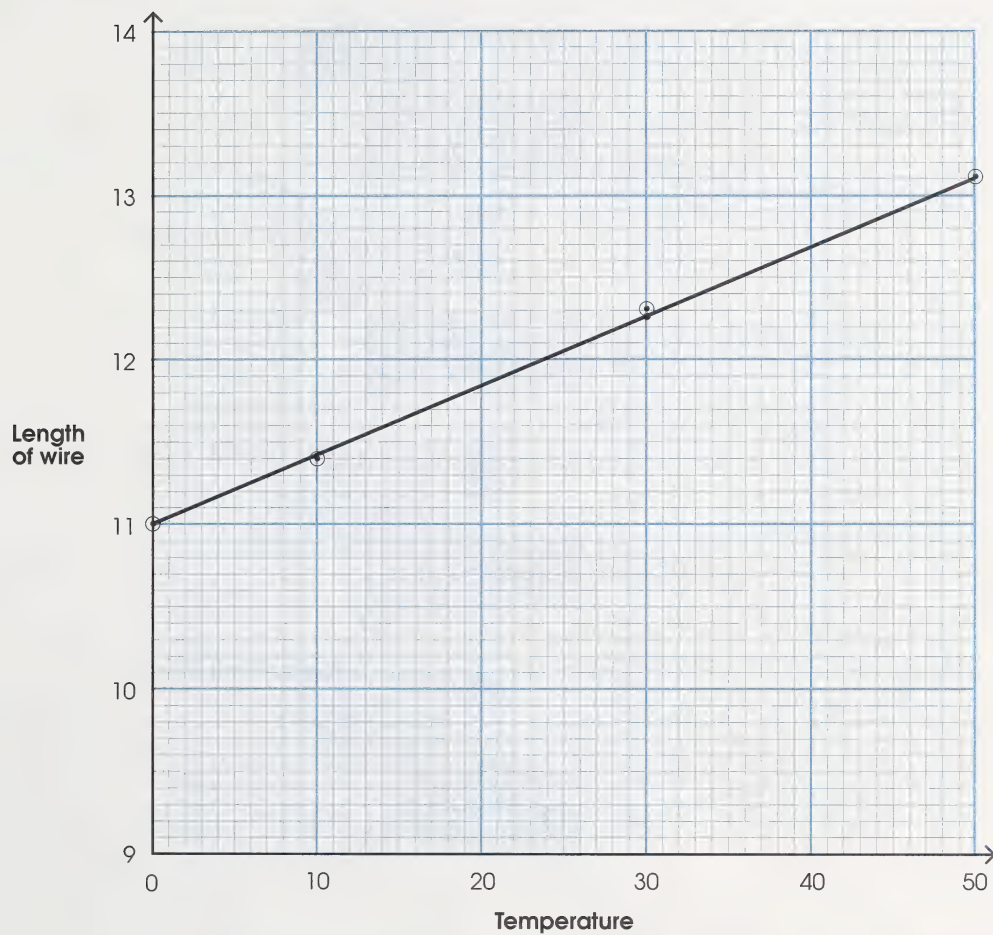
Check your answers by turning to the Appendix, Section 1: Extra Help.

Manipulating algebra takes a lot of practice. The techniques are learned gradually. Look at the following examples.

Example 1

Solve for *e* in the following equation.

$$4a^2b = d - ef$$

Add *ef* to both sides.

$$4a^2b + ef = d$$

Subtract $4a^2b$ from both sides.

$$ef = d - 4a^2b$$

Divide both sides by *f*.

$$e = \frac{d - 4a^2b}{f}$$

Example 2

Solve for t in the following equation.

$$d = \frac{1}{2}at^2$$

Divide both sides by $\frac{1}{2}a$. (Dividing by $\frac{1}{2}$ is like multiplying by 2.)

$$\frac{2d}{a} = t^2$$

Take the square root of both sides.

$$\sqrt{\frac{2d}{a}} = t$$

Rearrange the equation.

$$t = \sqrt{\frac{2d}{a}}$$

6. Try these questions.

   a. $v_f^2 = v_i^2 + 2ad$ Solve for d.

   b. $\frac{ab}{c} = \frac{e^2}{f}$ Solve for c.

Check your answers by turning to the Appendix, Section 1: Extra Help.

Enrichment

In the two options presented for Enrichment, you will see how the skills discussed in this section can be used during an experiment. You will also see how some shortcuts can save you time.

Do **either** question 1 **or** question 2.

1. An experiment was done by dropping a heavy ball off a 100-m high building. Photographs were taken and the speed of the ball was calculated for every half second until it landed. The results are shown in the following chart.
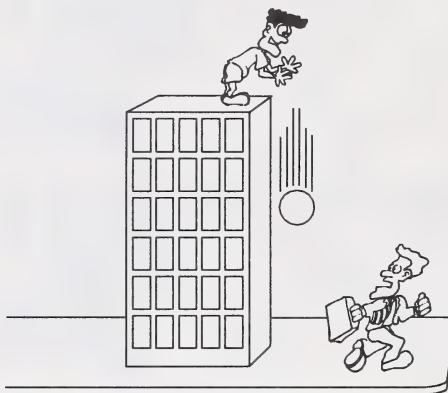
Time (s)	Speed of Ball (m/s)	Height Above Ground (m)
0	0	99.6
1.0	9.63	94.7
1.5	14.75	89.8
2.0	19.60	80.0
2.5	24.66	68.6
3.0	29.39	55.5
3.5	33.94	39.2
4.0	39.19	21.2
4.5	43.82	0

In Science 10 you learned about kinetic energy and potential energy. If you assume that the ball's mass is 0.625 kg, you can find these energies for the experiment.

Shortcut for Calculating Kinetic Energy

$$E_k = \frac{1}{2}mv^2$$

Find $\frac{1}{2}m$ and store it in your calculator's memory.

Recall the memory value and multiply it by the speed squared to find the kinetic energy.

kinetic energy – energy due to motion

Shortcut for Calculating Potential Energy

$$E_p = mgh$$

where $g = 9.80 \text{ m/s}^2$

Find mg and store it in your calculator's memory.

Recall the memory value and multiply it by the height to get the potential energy (E_p).

potential energy – energy that is stored and able to be used

a. Calculate the energies of the ball during its fall.

Time (s)	E_k (J)	E_p (J)
0		
1.0		
1.5		
2.0		
2.5		
3.0		
3.5		
4.0		
4.5		

b. Are the units the same for both potential and kinetic energy?
    Calculate the units for kinetic energy. Potential energy has been done
    for you.

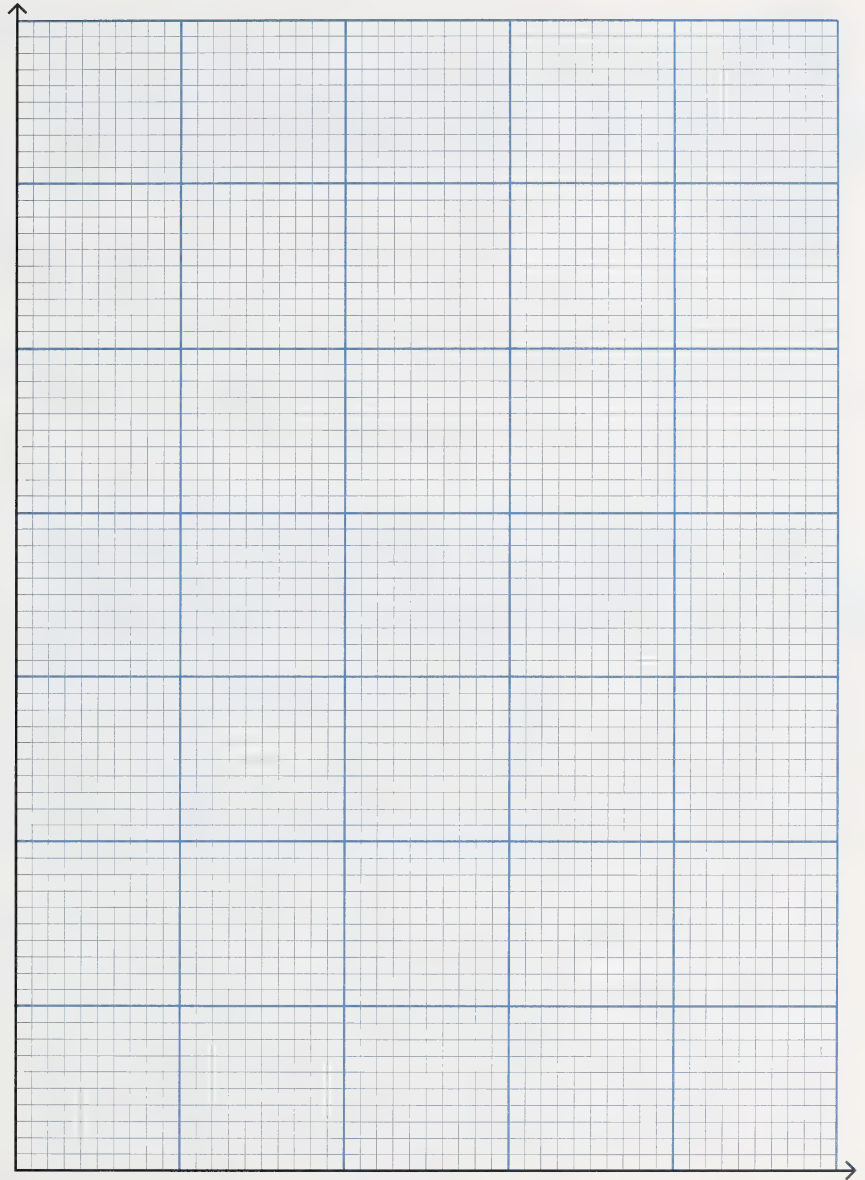$$E_p = mgh \qquad\qquad\qquad E_k = \frac{1}{2}mv^2$$

$$= kg \bullet \frac{m}{s^2} \bullet m$$

$$= \frac{kg \bullet m^2}{s^2}$$

$$= J$$

c. Now graph the data that you recorded in the chart. Choose a scale
    that will allow you to plot E_p versus time, E_k versus time, and total
    $E_p + E_k$ versus time all on the same graph. This means that you will
   plot three lines on the same graph.

d. What can you conclude about the total energy of the ball?

e. Where does the kinetic energy come from?

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Caution
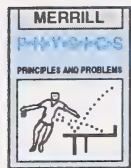
2. Turn to page 28 of your textbook and do the lab called Getting Straight. Note that you should modify the procedure by only doing the first four steps.

    If you do not have access to a sensitive balance (capable of measuring to 0.1 g), you will need to use the spring scale from your lab kit and substitute 2-inch by 4-inch lumber instead of wire. It is recommended that you cut a single piece of this lumber into three lengths of 50 cm, 30 cm, and 10 cm. If you are unfamiliar with the safe use of a woodsaw, you should have someone else cut the wood for you.

    a. Organize the data from your experiment into a neat chart.

    b. Graph the data as directed in the textbook. Use the graph paper that is provided.

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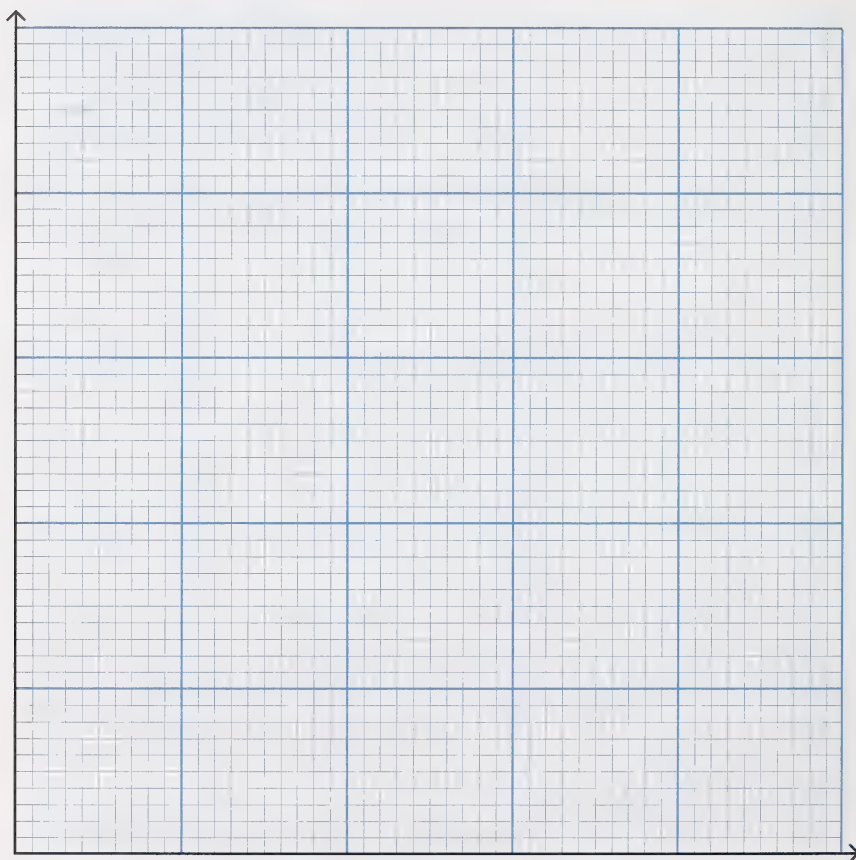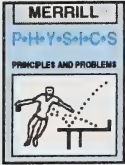
c.   Answer Analysis questions 1, 2, and 3 on page 28 of your textbook.

Check your answers by turning to the Appendix, Section 1: Enrichment.

Conclusion

Is physics mathematical? You bet! In order to be successful at physics, you must be reasonably good at certain kinds of math. If you have a good knowledge of the metric system and are able to do calculations with numbers and variables, interpret and make graphs, and round off numbers correctly, the door to physics is open to you!

Assignment
Booklet

ASSIGNMENT

Turn to your Assignment Booklet and do the assignment for Section 1.

2

Uniform Motion

WESTFILE INC.

When was the last time you travelled several hours by car? Whether it was a family vacation or a road trip for a sports team, the most common question was probably "How much longer until we're there?" What information would you need to answer this question? How would you calculate the answer?

In this section you will be studying the kind of motion that occurs when a car travels down a straight section of highway. You will learn how to answer questions using a variety of techniques, including measuring, graphing, and solving equations.

Activity 1: Basic Ideas

Your textbook mentions that motion can be described in three ways.

- Talk about it.
- Graph it.
- Put it in a mathematical equation.
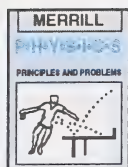
1. Read pages 40 to 42 in your textbook. Then fill out this chart to organize the terms that are defined on those pages.

Term	Meaning
reference point	
position	
distance	

vector – any measured quantity which has a size (magnitude) and a direction

**scalar** – any measured quantity that has size (magnitude) only (no direction)

If you need direction to describe something, it is called a **vector** quantity. If you do not need direction, it is called a **scalar** quantity.

2. Classify the terms *reference point*, *position*, and *distance* as vector or scalar quantities.

3. Read the following account from a pirate's treasure map.

   Begin at the base of the large tree on Hangman's Beach. Step off 38 paces straight north to find the treasure.

   a. What is the reference point on the map?

   b. What is the position of the treasure?

   c. Explain why the map would be useless without a reference point.

   d. Draw a diagram to explain why a map that gives only distance would make it much more difficult to find the treasure. What would someone have to do to find the treasure in this case?

Other important terms for studying motion are displacement and average velocity. Carefully read pages 43 and 44 in your textbook to discover the meanings of these words.
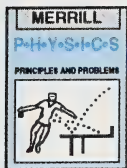
4. Define *displacement*.

5. Define *average velocity*.

6. Use Table 3-1 on page 43 of your textbook to answer the following questions.

    a. Determine the displacement and average velocity of the car between $t = 1.0$ s and $t = 2.0$ s.

    b. Determine the displacement and average velocity between $t = 2.0$ s and $t = 3.0$ s.

    c. During what clock times are the displacement and velocity of the car both zero?

average velocity – the change in position or the displacement in a particular time interval

Average velocity is defined on page 44 in a rather technical way. Another way to define it is as follows.

$$\text{average velocity} = \frac{\text{distance travelled}}{\text{time}} \text{ , including the direction}$$

7. Car A and Car B are moving equally fast, but they have different average velocities! Explain why.

45 km/h

45 km/h
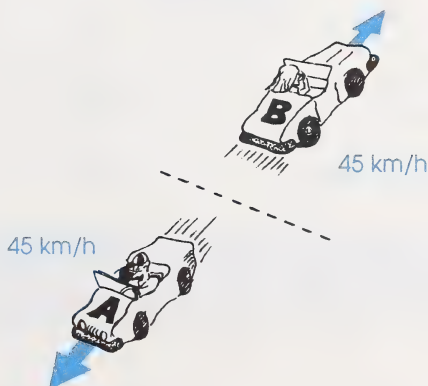
What if you don't care about indicating direction? Well, **speed** is used to tell how fast something is moving.

$$\text{average speed} = \frac{\text{distance travelled}}{\text{time taken}}$$

The easiest motion to analyse is motion that does not change velocity. That means that both the rate of travel and the direction of travel do not change. Any motion like this is called **uniform motion**.
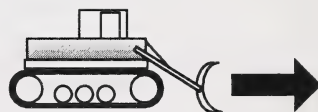
uniform motion – motion with an unchanging velocity; moving in a straight line at a constant speed

8. Are these pictures examples of uniform motion?
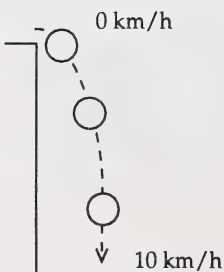
a.

10 m/s

b.

6 km/h

c.

0 km/h

10 km/h

d.

1.1m/s
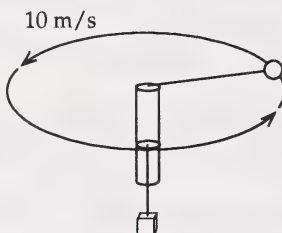
Your textbook talks about instantaneous and average quantities. This chart compares instantaneous and average quantities.

Comparison Chart for Instantaneous and Average Quantities	
Instantaneous Quantities	**Average Quantities**
• occur in a single instant of time	• occur over a period of time
• like a photograph	• like a motion picture
• examples of algebraic symbols: $\vec{v}$, $\vec{d}$	• examples of algebraic symbols: $\vec{v}_{ave}$, $\Delta\vec{d}$
• impossible to measure because the amount of time is too small	• able to measure because the amount of time is long enough

If an object moves with uniform motion, the average velocity and the instantaneous velocity are the same since the velocity is constant.

The notation for the variables can be simplified for questions that involve uniform motion. If the initial time is considered to be zero instead of Δt, the time interval can be written as t, the elapsed time. In a similar way, if the initial position is zero instead of $\Delta\vec{d}$, the displacement can be written simply as $\vec{d}$. Under these circumstances, the equation for uniform motion can be written as follows:

$$\vec{v} = \frac{\vec{d}}{t}$$

9. If you travelled from Calgary to Edmonton (a distance of about 300 km) in 3 h, what was your average speed? What was your average velocity?

10. When are the speed and the velocity of an object the same?

Check your answers by turning to the Appendix, Section 2: Activity 1.

Investigation: Uniform Motion

Since velocity is equal to the displacement over a period of time (for uniform motion), you can measure it two ways.

Method A: Time an object as it moves a known displacement.

Method B: Measure how far an object goes in a known time.

Science Skills

- [ ] A. Initiating
- [✓] B. Collecting
- [✓] C. Organizing
- [✓] D. Analysing
- [ ] E. Synthesizing
- [ ] F. Evaluating

PATHWAYS

If you are working in a group and have access to a long hallway, do either Method A or Method B. If you are working alone, do Method B.

Method A: Time to Move a Known Displacement

Materials

You will need the following materials for this investigation:

- measuring tape (metric) or metre stick
- heavy ball (a bowling ball, a shot, or a large steel ball bearing)

Procedure

Follow the procedure outlined in the Pocket Lab on page 52 of your textbook.

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Notes

- If the hall is not 30 m long, shorten up the distances (use 5 m, 10 m, and 15 m).

- One person at each displacement is fine if you do not have enough people for a group at each displacement.
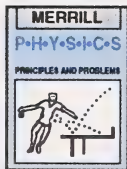
Observations

11. Fill in the following chart.

	Time (s)		
	Time to Reach 10 m	Time to Reach 20 m	Time to Reach 30 m
Trial 1			
Trial 2			
Trial 3			

Analysis

12. Fill in the following chart.

	Velocity (m/s)		
	Average Velocity over 10 m	Average Velocity over 20 m	Average Velocity over 30 m
Trial 1			
Trial 2			
Trial 3			

13. Did the velocity remain constant for the entire trip?

14. Do you have any information about the velocity in between the measured points (for example, at 23 m)?

15. What might you do in order to know more about the details of this motion?

16. If you observed any slowing-down effect, what do you think may have caused it?

End of Method A

Method B: Displacement Moved in a Known Time

Materials

You will need the following materials for this investigation:

- interval timer

- marble

- smooth surface (kitchen table)

- ruler or measuring tape (metric)

- butter, honey, vaseline, or oil (Just make sure that you have permission to put it on the table and that it can be cleaned up afterwards.)

In Science 10 you used interval timers to mark the position of an object a certain number of times per second. If you have access to one of these, use it. However, it's actually fun to try this experiment without one! All you need is something that makes a sound or something that makes a visible cue at consistent time intervals. Here are some examples.

Examples of Interval Timers	
Device	**Applications**
pendulums	They must keep even time intervals. Clocks work with them.
metronomes	They teach musicians to play in rhythm.
musicians	Since they practised with the metronome, they keep constant time!
a click recording	This was provided in the Science 10 lab kit.

metronome – an instrument that marks regular time intervals with audible ticks

Note: Recording studios use a "click track" when bands are recording music. This electronic metronome keeps everyone's time perfect.

Procedure

Step A: Calibrate your timer. Count the number of events that occur in 30 s. Then divide 30 by that number to get the time between events.

Example: A pop record is playing and you count 106 beats in 30 s.

$$\frac{30 \text{ s}}{106 \text{ beats}}$$

= 0.28 s apart

Step B: Turn on your timer and roll the marble across the table. Practise until you get it across in 5 to 10 time intervals.

Step C: Dip your finger in something greasy or sticky and roll the marble. Follow the ball across the table, touching the table "on the beat" where the marble is. (Good luck! This takes practice!)
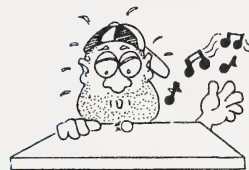
Step D: Measure the displacement between your fingerprints on the table. Measure to the centres of the fingerprints. Plot these measurements in the following chart.
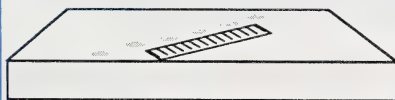
17. Record your data from Step D in this chart.

Interval Number	Displacement from Previous Smear (cm)	Total Displacement from First Smear (cm)
1		
2		
3		
4		
5		

18. Calculate the time between intervals.

19. Fill in this chart with the times you calculated in question 18.

Interval Number	Total Time(s)	Average Velocity (cm/s)
1		
2		
3		
4		
5		

20. Did the velocity remain constant for the entire trip?

21. Do you have any information about the motion in between your chosen time intervals (for example, at 0.40 s)?

22. What might you do in order to know more about the details of this motion?

23. If you observed a slowing-down effect, what do you think may have caused it?

Check your answers by turning to the Appendix, Section 2: Activity 1.

In the previous investigation it would have been nice to have been able to say how fast the object was going at some instant. To do this, you would have needed to measure an infinitely small interval. Unfortunately, that cannot be done. So how do you determine an instantaneous velocity? The answer involves learning some new graphing techniques.

Activity 2: Analysing Motion with Graphs ≣

If you want to graph an object's motion, it makes sense to graph the object's position versus time or, alternatively, its velocity versus time.

Position-Time Graphs

Read from page 48 to the middle of page 49 in your textbook to learn more about interpreting a position versus time graph.

1. Fill in this chart. It refers to Figure 3-5 on page 48 of your textbook.
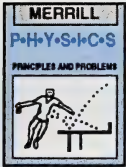
The graph is linear. This means that ...	➡	
The graph doesn't go through the origin. This means that ...	➡	
The slope of this graph is the ...	➡	

Check your answers by turning to the Appendix, Section 2: Activity 2.

> The **slope** of any **position-time** graph (or
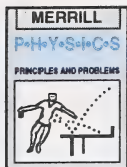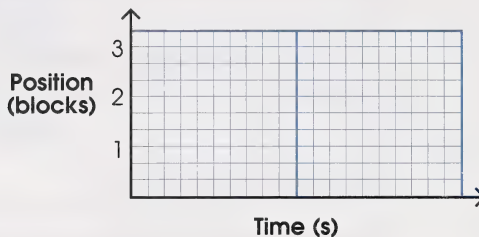> **displacement-time** graph) is always the
> **velocity** of the object involved.

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2. Do Concept Review questions 1.2 b. and 1.3 on page 49 of your textbook.

The following grid is provided for textbook question 1.3.

Position
(blocks)

3

2

1

Time (s)

Check your answers by turning to the Appendix, Section 2: Activity 2.

3. Try Practice Problems 10 and 11 on page 53 of your textbook.

Notice that the answer to Practice Problem 11. b. is zero. If an object moves
away from a position and returns to the same position, its displacement is
zero! That makes its average velocity zero as well.

Check your answers by turning to page 658 in your textbook.

4. A track athlete runs an 800-m race in 2 min 6 s. The track is a 400-m oval,
so the start and finish lines are in the same place. Find the athlete's
average velocity and average speed.

Velocity-Time Graphs

Read from page 54 to the top of page 55 in the textbook. Then look back to Figure 3-5 on page 48 to see the original data.

Compare the position versus time graph on page 48 to the velocity versus time graph on page 54.

The slope of the position-time graph is a constant 260 m/s. The velocity on the velocity-time graph is a constant value of 260 m/s. The slope of the position-time graph is equal to the velocity.

What if you knew the velocity-time information? Could you use it to find the total displacement?

You know that $\Delta \vec{d} = \vec{v}(\Delta t)$. Use this equation to find the displacement after 5 s.

$$\vec{d} = (+260 \text{ m/s})(5 \text{ s})$$
$$= +1500 \text{ m}$$

Now look at the velocity-time graph geometrically.
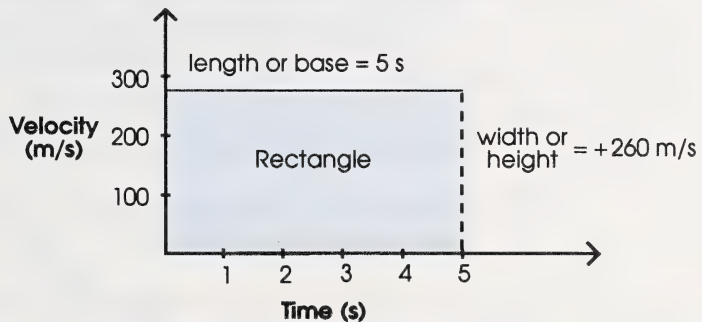
$$\text{area of rectangle} = \text{length} \times \text{width} = 5 \text{ s} (+260 \text{ m/s})$$
$$= +1500 \text{ m}$$

The two different ways of looking at the same motion gave the same answer.
The shaded area from 0 to 5 s in this graph is called the **area under the line
(or curve)**. In all velocity-time graphs, the area under the line (curve) is the
displacement for the chosen time interval.

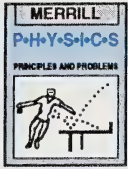5. Find the displacement during the first 13 s of the trip shown in this graph.
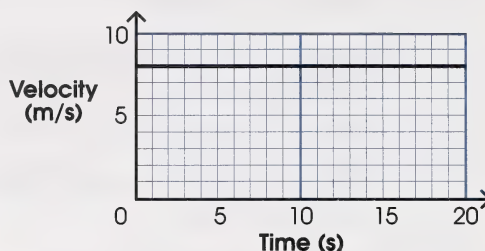
There are two really good things about these velocity-time graphs.

- The graph can be used to read the instantaneous velocity for any given
  time.

- The areas of simple geometric shapes can be used to find the
  displacement for any time interval, even if the motion is complex.

Check your answers by turning to the Appendix, Section 2: Activity 2.

Creating a Velocity-Time Graph

Suppose a bicycle travels west at 8.0 m/s for 10 s. It then stops for 3 s and
returns east at 4.0 m/s for 15 s.

What does a velocity-time graph for this look like?

Remember that velocity is a vector and must have a direction. Since west is the original direction, it could be considered positive. East would then have to be considered negative.

Velocity (m/s)	Time (s)
+ 8.0	0 - 10
0	10 - 13
- 4.0	13 - 28
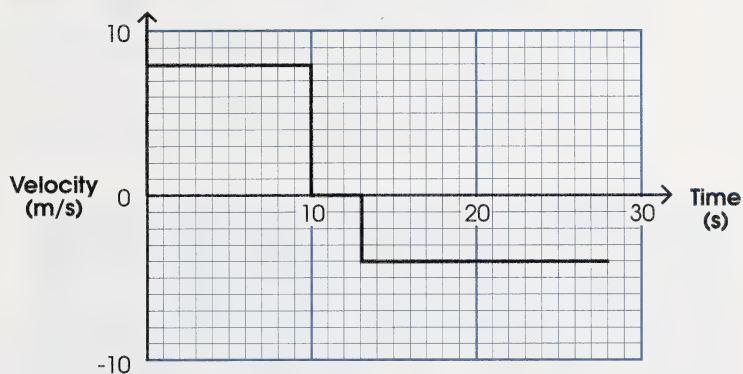
Determining the Displacement for the Positive Velocity
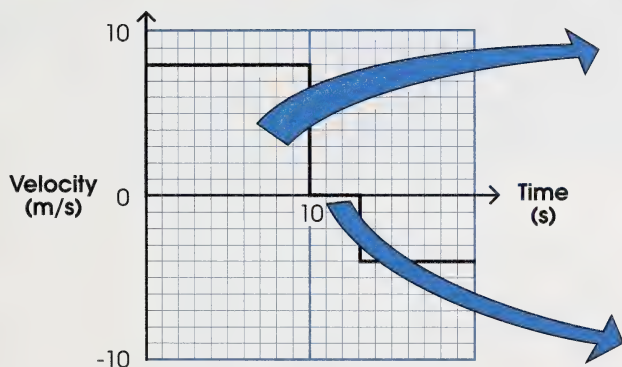
$\vec{d}$ = area under line

= area of a rectangle

= lw

= $(+8\,\text{m/s})(10\,\text{s})$

= $+80\,\text{m}$

Note that the area under this line segment equals zero since the line remains right on the x-axis.

Determining the Displacement for the Negative Velocity
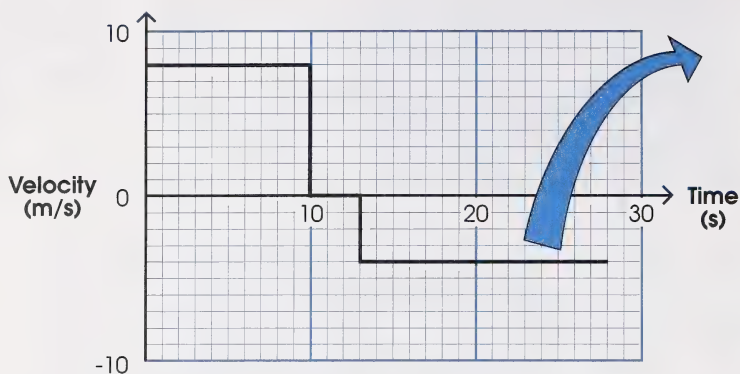
$\vec{d}$ = area under line

= area of a rectangle

= lw

= $(-4.0 \text{ m/s})(15 \text{ s})$

= -60 m

Note that areas below the horizontal axis are negative since $\bar{v}$ is negative.

Determining the Total Displacement
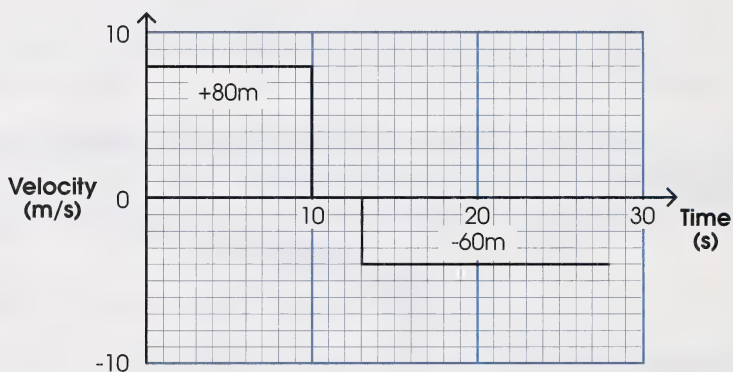
$\Delta\vec{d}$ = total area = $(+80 \text{ m})+(-60 \text{ m})$

= 20 m

Determining the Average Velocity

$$\vec{v}_{ave} = \frac{\Delta \vec{d}}{\Delta t} = \frac{+20\ m}{28\ s} = 0.71\ m/s$$

The average velocity was 0.71 m/s west.

Creating a Displacement-Time Graph

Construct a displacement-time graph for the same bicycle trip. Look at how the area under the line changes with time.

Time (s)	Area
0	0
5	8 m/s (5 s) = 40 m
10	8 m/s (10 s) = 80 m
13	80 m + 0 = 80 m
18	80 m + 5 s (−4 m/s) = 80 m − 20 m = 60 m
23	80 m + 10 s (−4 m/s) = 80 m − 40 m = 40 m
28	80 m + 15 s (−4 m/s) = 80 m − 60 m = 20 m

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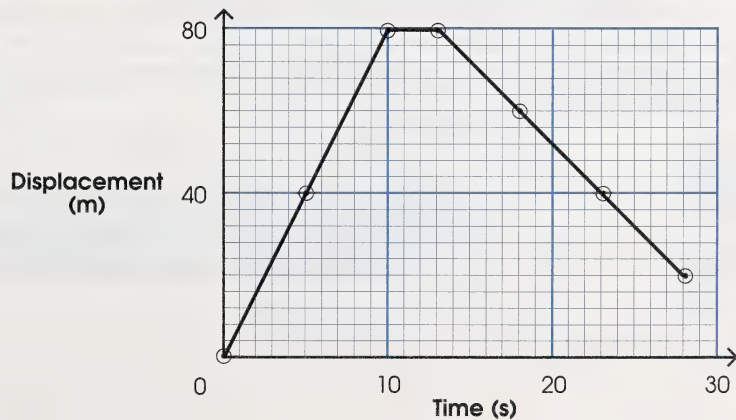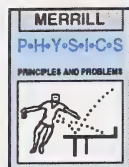
Wow! All that from one example! Now try one for yourself.

6. Do Practice Problem 18 on page 55 of your textbook.
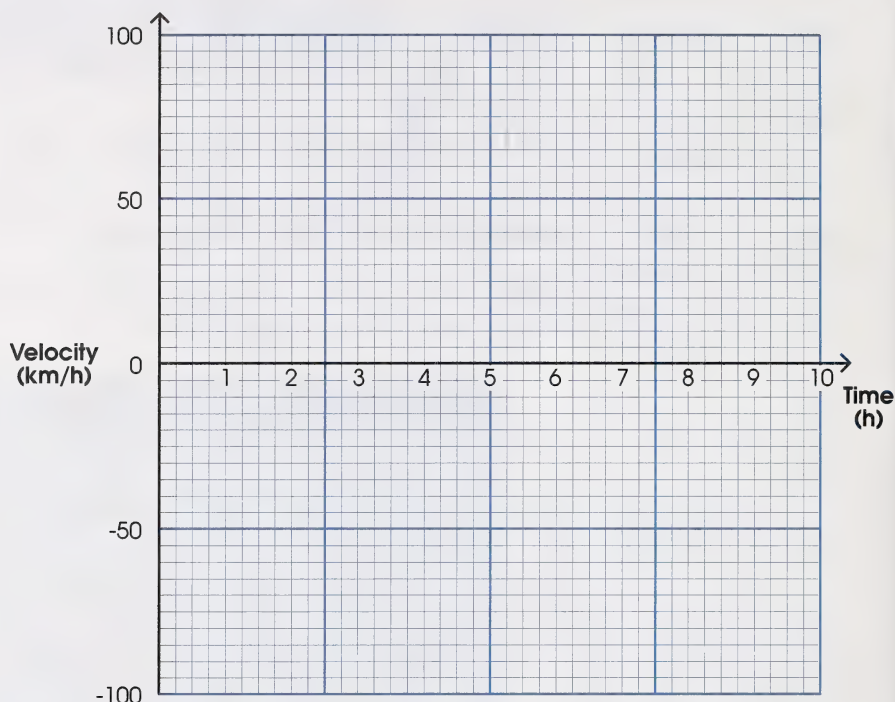
Have you ever wondered how science fiction movies that involve spaceships are filmed? How are the spaceships made to look like they are flying through space? Usually a 2-m model of the spaceship is positioned in a fixed position while the cameras move around it. Motion must be measured relative to a reference point or a frame of reference. If the camera is the reference point, it seems as if the spaceship is moving.

frame of reference – the
point of view of the observer

7. Do Practice Problem 20 on page 56 of your textbook.

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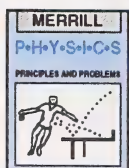
Check your answer by turning to page 659 in your textbook.

Activity 3: Algebraic Description of Motion

The algebraic description of uniform motion is as easy as physics gets. You have three quantities to relate to one another.

velocity ⇔ displacement ⇔ time
if direction matters

speed ⇔ distance ⇔ time
if direction doesn't matter

The equation relating these quantities is the definition of velocity.

$$\vec{v} = \frac{\vec{d}}{t}$$

The delta notation (Δ) is omitted when the velocity is constant ($\vec{v}_{average} = \vec{v}_{instantaneous}$).

Notice that the slope equation for a position-time graph is the same as the average velocity equation.

$$\text{slope} = \frac{\text{rise}}{\text{run}} = \frac{\Delta \vec{d}}{\Delta t} = \text{velocity (average)}$$

1. If you manipulate the equation, you will see it in another two forms.

    a. Solve the formula $\vec{v}_{ave} = \dfrac{\Delta \vec{d}}{\Delta t}$ for Δd.

    b. Solve the formula $\vec{v}_{ave} = \dfrac{\Delta \vec{d}}{\Delta t}$ for Δt.

Example

A train moves uniformly at 85.0 m/s and covers a displacement of 285 m. How long did this take? To solve this problem algebraically, do the following steps.

Step 1: List the variables involved.

$$\vec{v} = +85.0 \text{ m/s}$$
$$\vec{d} = +285 \text{ m}$$
$$t = ?$$

Note that displacement and velocity are both going in the same direction, which is labelled positive.

Step 2: Manipulate the equation and solve for the unknown variable.

$$t = \frac{\vec{d}}{\vec{v}}$$

Step 3: Substitute the numbers and units into the equation.

$$t = \frac{+285 \text{ m}}{+85.0 \text{ m/s}}$$

Step 4: Calculate the answer and round to the correct decimal place.

$$t = 3.35 \frac{\text{m}}{\text{m/s}}$$
$$= 3.35 \text{ s}$$

Step 5: Answer the problem.

It took 3.35 s to do this.

Try the following problems on your own.

2. An ant travels +1.00 m in a straight line in 4.05 s with uniform motion. What is its velocity?

3. Sound travels at 342 m/s in air. How far will a sound wave travel in 11.0 s?

Check your answers by turning to the Appendix, Section 2: Activity 3.

Example

A car travels at 45 km/h for 30 s. How far does it go? Normally you would multiply the velocity by the time to get an answer, but when you multiply km/h by s, you get km•s/h. Unfortunately, km•s/h is not an actual unit.

There are two solutions to this problem.

- Change km/h to m/s.
- Change s to h.

One method of changing km/h to m/s is shown on page 45 of your textbook. Here is another method.
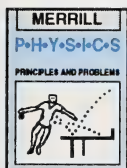
$$1 \text{ m/s} = ? \text{ km/h}$$

$$\frac{1 \text{ m}}{1 \text{ s}} = \frac{0.001 \text{ km}}{1 \text{ s}} = \frac{0.001 \text{ km}}{\frac{1}{3600} \text{ hr}} = 3.6 \text{ km/h}$$

Change m to km.   Change s to h.

You should memorize this conversion factor.

$$1 \text{ m/s} = 3.6 \text{ km/h}$$

Remember that conversions that involve time **cannot** be done with just a decimal shift.

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How about changing from cm/s to m/s? Notice that the time does not change, so it's just like changing from cm to m.

$$76 \text{ cm/s} = 0.76 \text{ m/s}$$

4. Now try the following problems from your textbook.

   a. Do Practice Problem 1 on page 45.

   b. Do Practice Problem 2 on page 45.

   c. Do Practice Problem 6 on page 47.
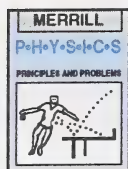
Check your answers by turning to pages 657 and 658 in your textbook.

How else can these questions become complicated? Consider the following examples.

Example 1: Using Tougher Numbers

This doesn't look too hard to me.

Light travels at 3.00×10^8 m/s. The distance from the sun to Earth is 1.49×10^{11} m. How long does it take light from the sun to reach Earth?

$$t = \frac{\vec{d}}{\vec{v}} = \frac{+1.49 \times 10^{11} \text{ m}}{+3.00 \times 10^8 \text{ m/s}} = 497 \text{ s} = 8.28 \text{ min}$$

Positive signs have been added to remind you that these displacements and velocities are vectors in the original direction, which is considered to be positive.

Example 2: Figuring Out $\Delta \vec{d}$ or Δt First

This is slightly more difficult.

Kasim jogs from a point 1.0 km from home to a point 11.5 km from home. He starts at 10:00 p.m. and finishes at 11:20 p.m. What is his average velocity?

$$\vec{v}_{ave} = \frac{\Delta \vec{d}}{\Delta t} = \frac{(11.5 \text{ km} - 1.0 \text{ km})}{(11:20 \text{ p.m.} - 10:00 \text{ a.m.})} = \frac{+10.5 \text{ km}}{1 \text{ h } 20 \text{ min}}$$

$$= \frac{+10.5 \text{ km}}{1.333 \text{ h}}$$

$$= 7.88 \text{ km/h}$$

Example 3: Making the Motion More Complex

Hmm!

Jodi walks east at 4.0 km/h for 30 min. She then stops for 10 min. Finally she goes west at 3.0 km/h for half an hour. Find her average velocity.

Jodi's walk can be broken down into three components.

- east at +4.0 km/h for $\frac{1}{2}$h

$$\vec{d} = \vec{v}t = +2.0 \text{ km}$$
$$= 2.0 \text{ km east}$$

- stops

$$\vec{v} = 0$$

- west at – 3.0 km/h for $\frac{1}{2}$h

$$\vec{d} = \vec{v}t = -1.5 \text{ km}$$
$$= 1.5 \text{ km west}$$

Positive vectors were considered east, since east was the original direction.

$$\Delta\vec{d} = 2.0 \text{ km} - 1.5 \text{ km} = +0.5 \text{ km}$$
$$= 0.5 \text{ km east}$$

$$\Delta t = 30 \text{ min} + 10 \text{ min} + 30 \text{ min} = 70 \text{ min}$$

$$= \frac{70}{60} = 1.167 \text{ h}$$

$$\vec{v}_{ave} = \frac{\Delta\vec{d}}{\Delta t}$$
$$= \frac{+0.5 \text{ km}}{1.167 \text{ h}}$$
$$= 0.43 \text{ km/h}$$

Jodi's average velocity was 0.43 km/h east.

Example 4: Deciding on a Strategy to Solve a Problem

Ouch!

If you leave right now, you must average 100 km/h in order to catch a plane. The airport is 22 km away. You only average 80 km/h for the first 11 km. What must your average velocity be in the next 11 km in order to catch your plane?

total time taken if you average 100 km/h over 11 km

$$\Delta t = \frac{\Delta \vec{d}}{\vec{v}_{ave}} = \frac{+22 \text{ km}}{+100 \text{ km/h}} = 0.22 \text{ h}$$

But you average only 80 km/h over 11 km.

$$t = \frac{\vec{d}}{\vec{v}} = \frac{+11 \text{ km}}{+80 \text{ km/h}} = 0.1375 \text{ h}$$

time left to complete the trip

$$0.22 \text{ h} - 0.1375 \text{ h} = 0.0825 \text{ h}$$

new average velocity (covers 11 km in 0.0825 h)

$$\vec{v}_{ave} = \frac{\Delta \vec{d}}{\Delta t} = \frac{+11 \text{ km}}{0.0825 \text{ h}} = 133 \text{ km/h}$$

You must average 133 km/h over the next 11 km to catch the plane.

These examples illustrate some important points.

- You may know of other methods to solve these problems. As long as your solution follows the recommended guidelines given earlier, that's great!

- When you do a complicated question with a lot of steps in it, do not round off for significant digits until the very end! Keep all the numbers in your calculator's memory. Use the unrounded numbers for calculations.

  For instance, in Example 4, the second step gives 0.1375 h for a number. This has too many significant digits, but since it is not the final answer, all the digits are used. Rounding off only occurs at the very last step.

5. Try the following textbook problems.

   a. Do Problem 5 on page 59.

   b. Do Problem 10 on page 60.

   c. Do Problem 12 on page 60.

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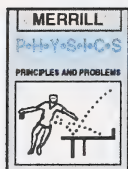
Check your answers by turning to the Appendix, Section 2: Activity 3.

Follow-up Activities

If you had difficulties understanding the concepts in these activities, it is recommended that you do the Extra Help. If you have a clear understanding of the concepts, it is recommended that you do the Enrichment.

Extra Help

1. Match the terms on the left with the definitions on the right. You will
    find these definitions either in the textbook or in this module.

    Term   **Description**

    position _____   a. the place where positions are
                                                  measured from
    velocity _____
                                              b. how fast (direction is not stated)
    vector _____
                                              c. how fast in a particular direction
    displacement _____
                                              d. where you are from a certain place
    scalar _____
                                              e. how far (direction is not stated)
    speed _____
                                              f. any measured quantity in which
    reference point _____   the direction matters

    distance _____   g. any measured quantity that has
                                                  no direction

                                              h. a change of position

To actually measure speed or velocity, you need a distance and a time to
calculate with.

2. Suppose that these dots show you where an object was at time intervals
    of 1/10 s (or 0.10 s). Find the average velocity of the object.

If you look at a position-time graph, you see a picture of where an object is in relation to some reference point.
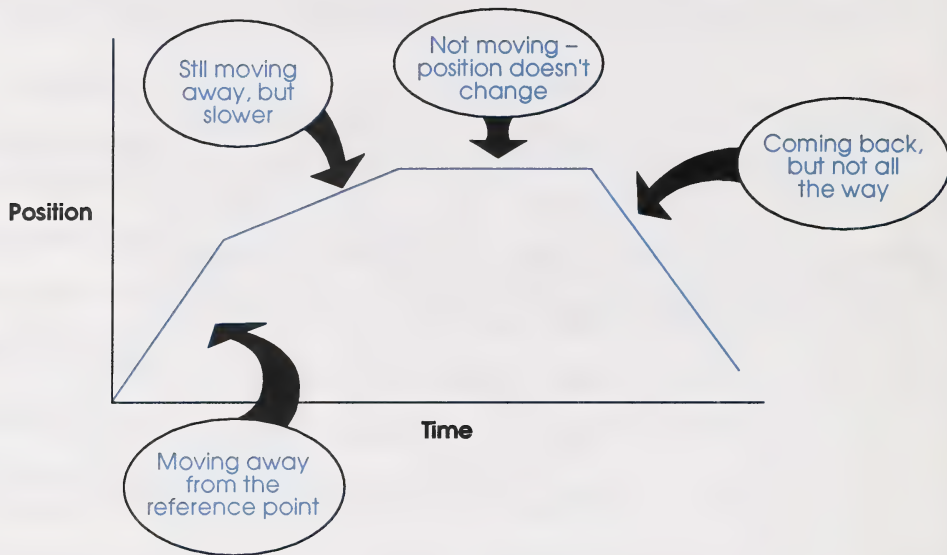
Looking at a velocity-time graph tells you how fast an object is going over time.
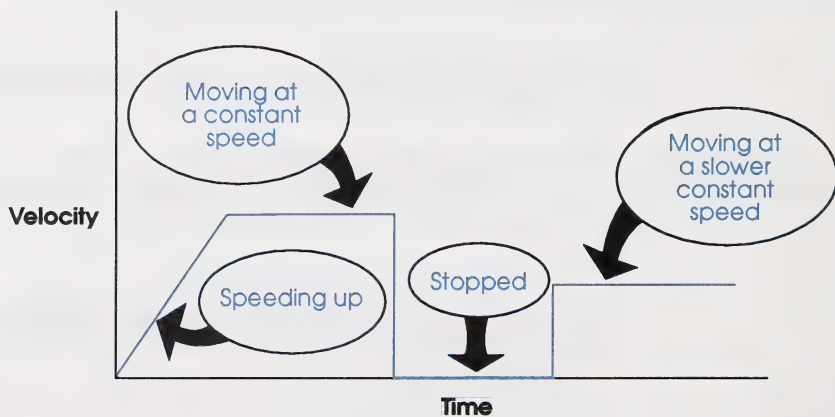
Look at the relationship between the two kinds of graphs.

slope = 0

slope = 0.86 m/s

Position (m)

slope = 2.5m/s

Time (s)
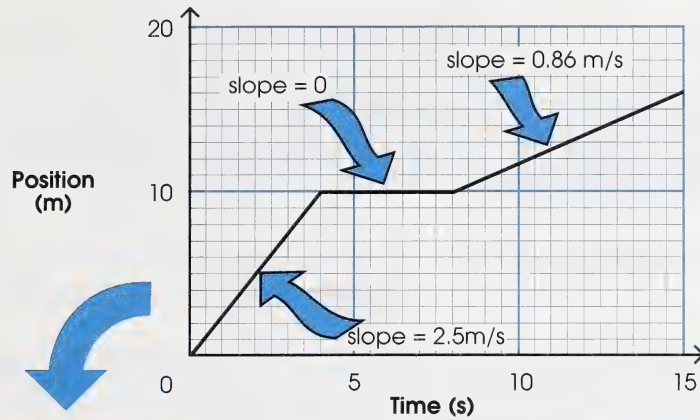
The slope of the position-time graph will be the value for the velocity-time graph.

The area under the line on the velocity-time graph will be the value for the position-time graph.

Velocity (m/s)

area = 10m

area = 6m

Time (s)

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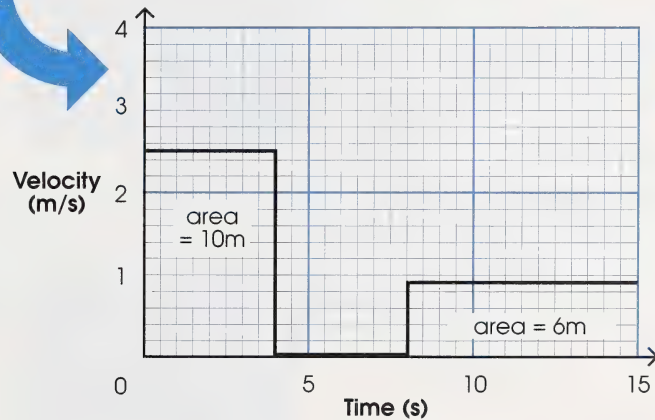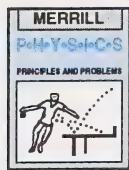
3. Do questions 9 and 10 on page 689 of your textbook.

4. Make a velocity-time graph from the position-time graph shown for question 9 on page 689 of your textbook. Remember, the slope of the position-time graph will be the value of the velocity-time graph.
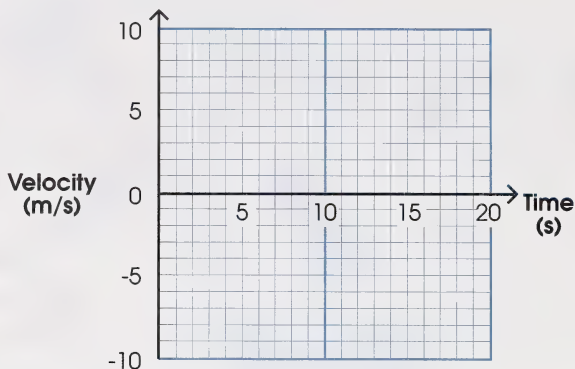
Check your answers by turning to the Appendix, Section 2: Extra Help.

Solving equations to answer problems is a matter of organizing your thoughts. Use the following steps to answer questions 5, 6, 7, and 8.

Step 1: List the variables.
Step 2: Manipulate the equation.
Step 3: Substitute in the data.
Step 4: Solve the equation.
Step 5: State the answer.

5. A car moves at a constant 87 km/h for 4.5 h. How far did it go?

6. A bike travels 4.85 km in 12.0 min. Find its average velocity.

7. How long will it take a bug to walk across a 4.86-m long wall if it moves at 1.10 cm/s?

8. Do questions 3 and 5 on page 689 of your textbook.
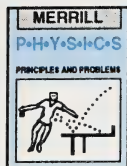
Check your answers by turning to the Appendix, Section 2: Extra Help.

Maggie walks north at 6.0 km/h for 20 min and then walks south at 5.0 km/h for 30 min. Find her average velocity.

Note: It is very important to keep the directions straight in the solution. In this case, north is considered to be positive and south is considered to be negative.

This problem can be solved in two parts since Maggie's walk can be split into two directions – north and south.

First find Maggie's displacement for the first part of her walk.

$$\vec{d} = \vec{v}t$$
$$= +6.0 \text{ km/h} \times \frac{1}{3} \text{ h}$$
$$= 2.0 \text{ km}$$

$20 \text{ min} = \frac{1}{3} \text{ h}$

Then find Maggie's displacement for the second part of her walk.

$$\vec{d} = \vec{v}t$$
$$= -5.0 \text{ km/h} \times \frac{1}{2} \text{ h}$$
$$= -2.5 \text{ km}$$

$30 \text{ min} = \frac{1}{2} \text{ h}$

Find Maggie's total displacement.

$$\Delta \bar{d} = (+2.0 \text{ km}) + (-2.5 \text{ km})$$
$$= -0.5 \text{ km}$$

What was the total time that Maggie walked for?

$$\Delta t = (20 \text{ min}) + (30 \text{ min})$$
$$= 50 \text{ min}$$
$$= 0.833 \text{ h}$$

Now you can calculate Maggie's average velocity.

$$\bar{v}_{ave} = \frac{\Delta \bar{d}}{\Delta t}$$
$$= \frac{-0.5 \text{ km}}{0.833 \text{ h}}$$
$$= -0.6 \text{ km/h}$$

Maggie's average velocity was 0.6 km/h south.

9. Try questions 2 and 7 from page 689 of your textbook.

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Check your answers by turning to the Appendix, Section 2: Extra Help.
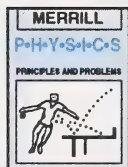
Enrichment

PATHWAYS

If you like researching and learning about new and interesting ideas, do question 1. If you enjoy solving more challenging problems, do question 2.

1. Light travels at 3.00×10^8 m/s. This is very fast, but not instantaneous. We see things not as they occur, but when the light reflected by them reaches us. For example, since it takes light from the sun $8\frac{1}{3}$ min to reach us, we see the sun as it was $8\frac{1}{3}$ min ago, not as it is now.

   Consider the following statement.

   > Looking farther out in space is the same as looking back in time.

   Huge telescopes are being constructed both on Earth and in space to see as far out as we can. Why do you think this is so important to cosmologists? Research this question and write a few paragraphs to answer it.

cosmology – the study of the origin of the universe

2. Try these problems.

    a. Here is a velocity-time graph for two different cars. They began their
        trips in the same place. Find the largest displacement between them.
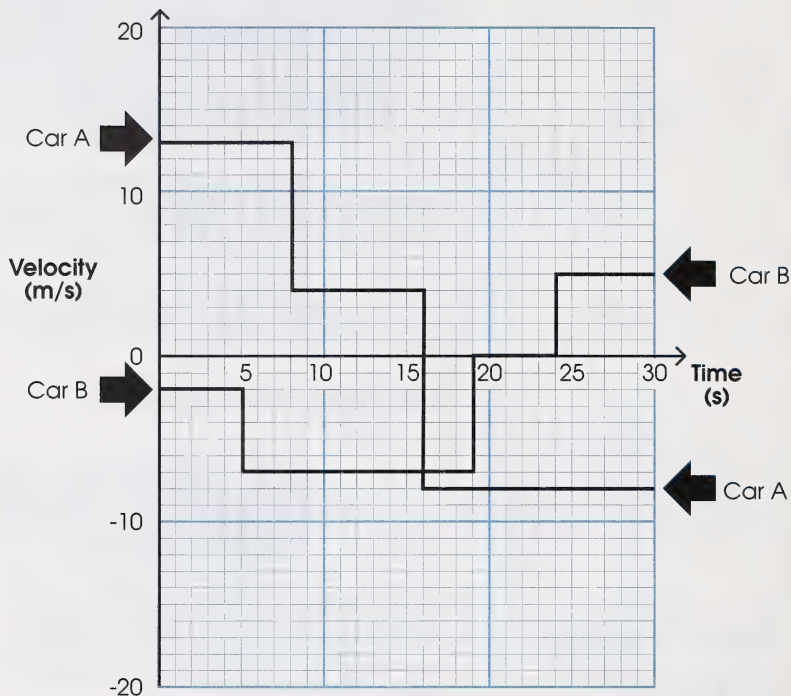
    b. Norm leaves town at 8:00 a.m. and travels at 65 km/h down the
        highway. Lisa leaves town at 9:30 a.m. and travels at 95 km/h in the
        same direction. How far does Lisa travel to catch up to Norm? What
        time is it when she catches up to him?

    c. Do question 4 on page 689 of your textbook.
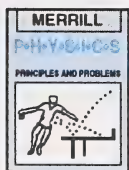
    Check your answers by turning to the Appendix, Section 2: Enrichment.

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Conclusion

In this section you learned how to talk about uniform motion, how to graph uniform motion, and how to solve algebraic problems dealing with uniform motion.
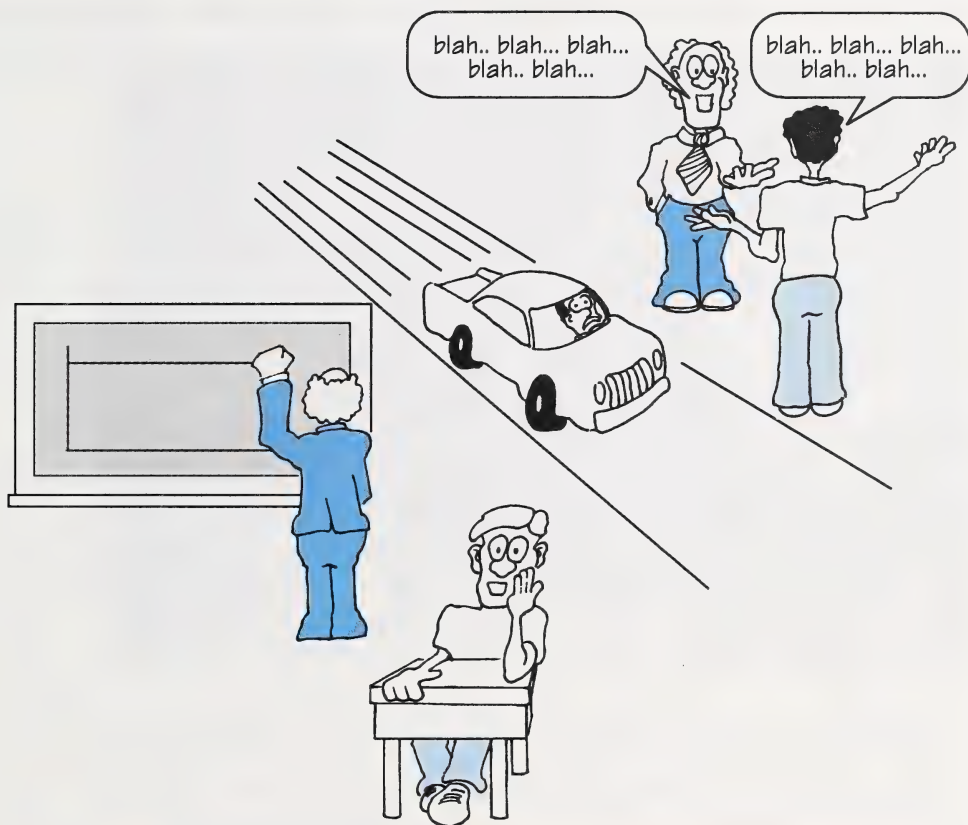
ASSIGNMENT

Turn to your Assignment Booklet and do the assignment for Section 2.

Assignment Booklet

3

Accelerated Motion

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After hiking for several hours, you finally reach the summit of the mountain. What a view! Far below lies a dried out creek bed and lots of rocks. Curious to see how high up you are, you gently toss a pebble over the edge and listen for the sound of it as it strikes the rocks far below. How would you estimate how high you are? Could you use the time it takes the pebble to reach the bottom to calculate your height?

Before you answer any of these questions, you should know something about the type of motion that describes how objects fall through the air. In this section you will learn the terminology, the graphical descriptions, and the equations that describe the motion of falling objects. You will also look at other examples of this type of motion.

Activity 1: What Is Acceleration?

acceleration – the ratio of an object's change in velocity to the change in time

Most people think that **acceleration** means "speeding up". That is correct, but only partly so.

> Acceleration is the rate of change of velocity.

To get a sense of this, look at this example.

> You are sitting on your bike at the top of a hill. You push off and coast down the hill to a speed of 10 m/s in a 5-s period.

Did you speed up? Sure! But how quickly did you speed up? On average, how much did your speed increase each second?

> Your speed went from 0 m/s to 10 m/s in 5 s. That's a change of 2 m/s each second.

That's it! Your acceleration was 2 m/s per second.

Read pages 62 to 65 in your textbook. You will notice that the textbook distinguishes between average acceleration and instantaneous acceleration. This will be explained later. For now, focus on the equation and how it is used in the first Example Problem.

1. Do Practice Problem 1 on page 66 of your textbook.

> Check your answers by turning to page 659 in your textbook.

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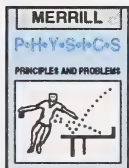
Acceleration units look strange the first time they are encountered. Look at these examples of acceleration.

Velocities		Change in Velocity	Time Interval	Acceleration
Initial	Final			
0 m/s	10 m/s	+10 m/s	5 s	$\dfrac{10 \text{ m/s}}{5 \text{ s}} = 2 \text{ m/s}^2$
10 km/h	20 km/h	+10 km/h	2 s	$\dfrac{10 \text{ km/h}}{2 \text{ s}} = \dfrac{5 \text{ km}}{\text{h} \bullet \text{s}}$
2 km/h	100 km/h	+98 km/h	10 h	$\dfrac{98 \text{ km/h}}{10 \text{ h}} = 9.8 \text{ km/h}^2$
30 m/s	10 m/s	−20 m/s	4 s	$\dfrac{-20 \text{ m/s}}{4 \text{ s}} = -5 \text{ m/s}^2$

There are two things to note about acceleration.

- Acceleration is a velocity change divided by a time interval and its unit must reflect this. Since units multiply and divide as algebraic symbols, acceleration units appear as follows:

$$\frac{m}{s} \div \frac{s}{1}$$
$$= \frac{m}{s} \times \frac{1}{s}$$
$$= \frac{m}{s \bullet s}$$
$$= \frac{m}{s^2}$$

• If an object **slows down**, the acceleration will be a **negative** value.

deceleration – the act of
slowing down

Slowing down is
a **deceleration**.

Yes, but that's the same
as a negative acceleration!

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2. Try Practice Problems 2, 3, and 4 on page 66 of your textbook. If you
    need more assistance, look at the second Example Problem on page 65.

Check your answers by turning to pages 659 and 660 in your textbook.

3. Read the Physics and Technology box on page 68 of your textbook. A
    driver slows down more slowly with an air bag than without one. What
    does the airbag do to the value of the driver's acceleration?

Recall that uniform motion is motion with a constant velocity. How common
is uniform motion?

If you drive from Lethbridge to Grande Prairie in 15 h (a distance of 935 km),
your average speed is 62 km/h. Did you really drive that slowly, or does the
15 h include stops? Did you keep exactly the same speed the whole time?
Probably not, even if you used cruise control.

Uniform motion is not common in the everyday way we move around. However, light and sound do move with uniform motion, or pretty close to it.

Uniform motion means that acceleration equals zero. Since uniform motion is not all that common, accelerated motion must be more common. Every time you change your velocity (speed or direction) you are accelerating!

Great! Accelerated motion is more common! That means more complicated math.

Yes, it does, but things could be worse!

Worse, how ?

The accelerations can be changing, too!

Yikes! Then what?

You need a math called calculus. We won't go that far.

Whew!
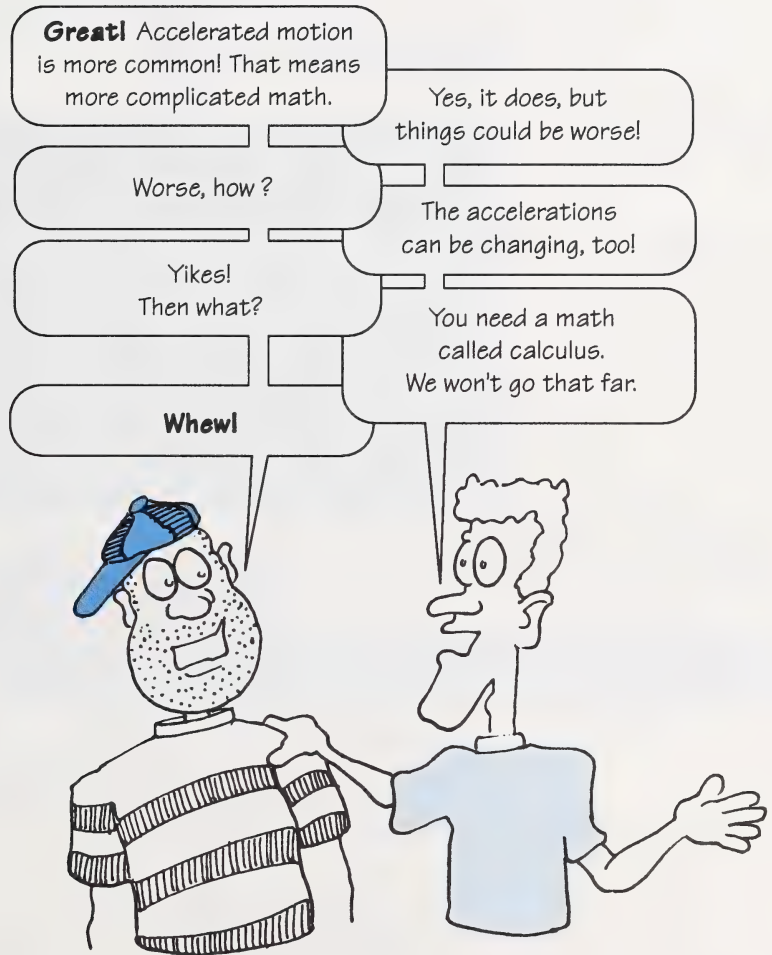
The simplest kind of accelerated motion is where the acceleration rate is constant. Bungee jumpers experience this in the first few seconds of their jump when they are in free fall.

4. Describe how your velocity would change if you were travelling with a constant or uniform acceleration.

Now try to sort out the difference between average and instantaneous acceleration.

Comparison Chart for Average and Instantaneous Acceleration	
Average Acceleration	**Instantaneous Acceleration**
• occurs over a measurable time interval $\vec{a}_{ave} = \dfrac{\text{change in velocity}}{\text{time interval}}$ $= \dfrac{\Delta \vec{v}}{\Delta t}$	• occurs during an instant of time which is too small to measure $\vec{a} = \dfrac{\text{change in velocity}}{\text{infinitely small time}}$ $= \dfrac{\Delta \vec{v}}{t}$

If acceleration is constant, average acceleration and instantaneous acceleration are equal.

The equations for uniform (constant) acceleration are based on the idea that the initial time in any application will be zero. This means that instead of Δt, the time interval can be represented by t, the elapsed time. The important variables are then written as follows:

- $\vec{v}_i$ initial (or starting) velocity
- $\vec{v}_f$ final (or end) velocity
- t time interval
- $\vec{a}$ acceleration

$$\boxed{\begin{array}{c} \textbf{Uniform Acceleration} \\[4pt] \bar{a} = \dfrac{\bar{v}_f - \bar{v}_i}{t} \end{array}}$$

Manipulating this equation gives you some other important equations.

$$\boxed{\bar{a} = \dfrac{\bar{v}_f - \bar{v}_i}{t}}$$

Multiply both sides by t.

$$\boxed{\bar{a}t = \bar{v}_f - \bar{v}_i}$$

Add $\bar{v}_i$ to both sides and rearrange.

$$\boxed{\bar{v}_f = \bar{v}_i + \bar{a}t}$$

This equation is very important for physics!

5. Look on page 69 of your textbook. Read the Example Problem and then try Practice Problems 9, 10, and 11. (For question 10, be careful with the units. Convert speed to m/s or convert acceleration to km/h•s first.)

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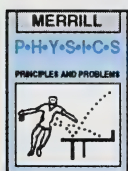
Check your answers by turning to the Appendix, Section 3: Activity 1.

Activity 2: Acceleration Graphs

In Section 2 you saw that a position-time graph can tell you the instantaneous velocity of an object. You can also do the same thing for acceleration.

> In all graphs, slope measures a rate of change. Since acceleration is a rate of change of velocity, the **slope** of a **velocity-time graph** is the **acceleration** of the moving object.

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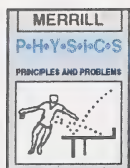
1. Read pages 66 and 67 in your textbook. Then do Practice Problems 6 and 7 on page 68.

It is important to remember the following things about the slope of a line.

| Line rises to the right | → | Positive slope |
| Line falls to the right | → | Negative slope |
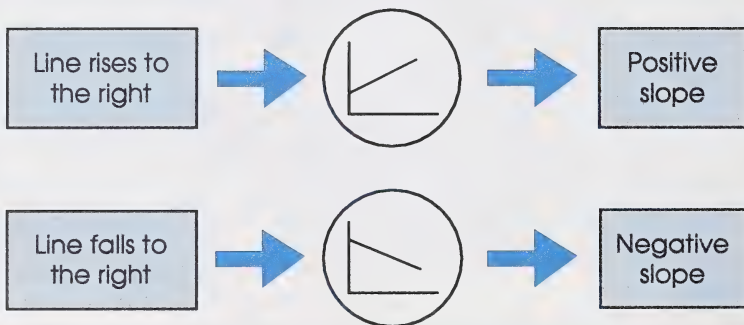
Check your answers by turning to page 660 in your textbook.

Look at this velocity-time graph for an object that speeds up from rest at a rate of 2 m/s every second (acceleration = 2.0 m/s^2).

Velocity vs. Time

Velocity (m/s) vs. Time (s)
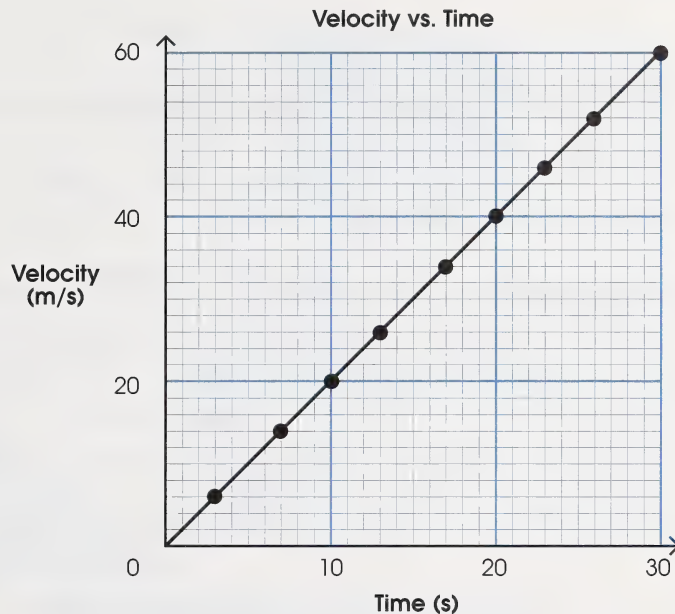
2. Does the slope equal the acceleration?

3. What feature of the graph tells you that the acceleration is constant for this motion?

Check your answers by turning to the Appendix, Section 3: Activity 2.

Here is another concept that applies if the acceleration is constant. The average velocity can be found by calculating the average of the initial and final velocities.

$$\vec{v}_{average} = \frac{\vec{v}_f + \vec{v}_i}{2}$$

In the preceding graph $v_i = 0$ and $v_f = +60$ m/s.

$$\bar{v}_{average} = \frac{60 \text{ m/s} + 0}{2} = 30 \text{ m/s}$$

How far would you go if your average velocity was + 30 m/s and you went for 30 s?

$$\Delta \vec{d} = \bar{v}_{ave} \left(\Delta t \right)$$
$$= \left(+30 \text{ m/s} \right) \left(30 \text{ s} \right)$$
$$= 900 \text{ m}$$

What is the area under the line of this graph for the 30-s time interval?
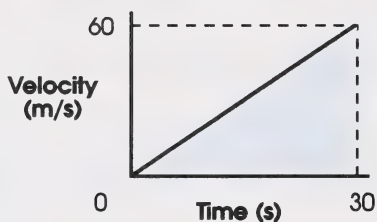
Since the shape under the line is a triangle, you can use the formula for the area of a triangle to find how far you went.

$$\text{area} = \frac{1}{2} ab$$
$$= \frac{1}{2} \left(60 \text{ m/s} \right) \left(30 \text{ s} \right)$$
$$= 900 \text{ m}$$

Finding the area under a velocity-time graph works even if the velocity is changing.

The acceleration-time graph for this motion follows. Remember that the acceleration is a constant 2.0 m/s^2 for the whole trip.
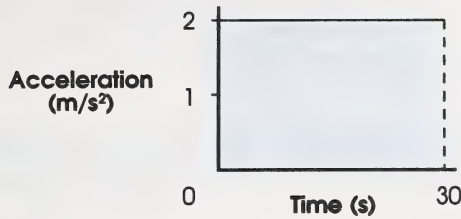
Acceleration (m/s²)

What do you think the area under the line on this graph represents?

$$\text{area} = lw$$
$$= \left(2 \text{ m/s}^2\right)\left(30 \text{ s}\right)$$
$$= 60 \text{ m/s}$$

The unit m/s implies a velocity.

> The **area under** an **acceleration-time** graph is the **change in velocity** of the moving object.
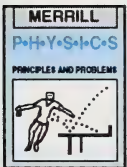
4. Do question 2 from Chapter 4 on page 690 of your textbook.

5. a. Make an acceleration-time graph from the velocity-time graph shown in question 2 on page 690.
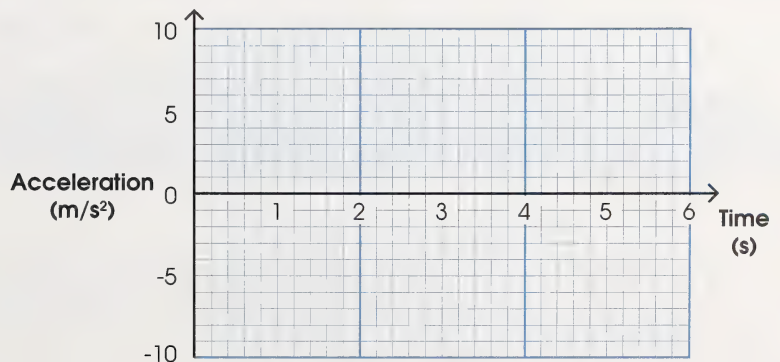
Acceleration (m/s²)

b. Find the area under the line for the 6-s interval. What does it represent?

If you had access to an interval timer, you could measure an acceleration. However, the process is quite complex, so a hypothetical experiment and data are provided for you.

Investigation: Measuring Acceleration

There are two possible methods that could be used here. You could either drop a weight which pulls the paper tape through the timer, or set the table on an incline and let an object pull the tape through the timer as it rolls.
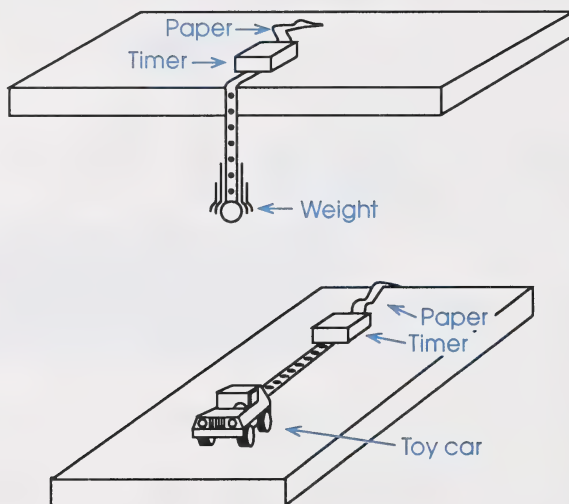
In either case, the results are similar. The tape in the margin shows the results of this experiment. This tape will be used for the analysis.

The analysis is broken down into a number of steps.

Step 1: Measure the position of each dot from the starting point.

Step 2: Measure the displacement between adjacent dots.

6. Complete the rest of this chart using the first part of the data as an example.

Time		Position from Start (cm)	Displacement Between Dots (cm)
Dot	**(s)**		
First	0	0	
			1.0
Second	0.10	1.0	
			1.5
Third	0.20	2.5	
			2.0
Fourth	0.30	4.5	
			2.5
Fifth	0.40	7.0	
Sixth	0.50		
Seventh	0.60		
Eighth	0.70		
Ninth	0.80		

7. Why are the dots on the tape getting farther apart?

Check your answers by turning to the Appendix, Section 3: Activity 2.

Time intervals are every 0.10 s.

Start
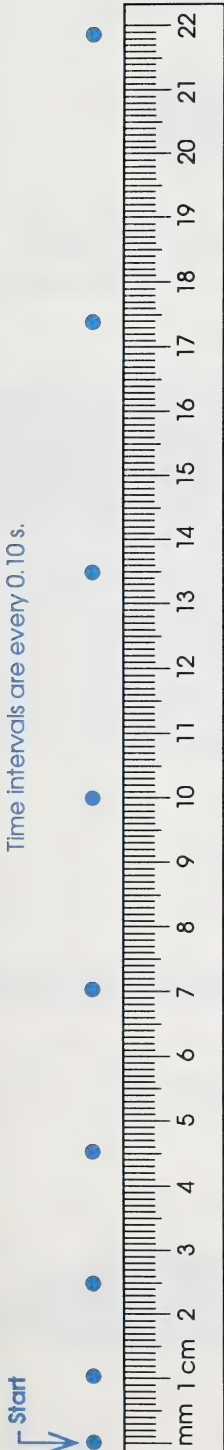
Step 3: Calculate the average velocities for each of the time intervals.

$$\bar{v}_{ave} = \frac{\Delta \bar{d}}{\Delta t} = \frac{\text{displacement between dots}}{\text{time interval}}$$

The displacement between the dots is known from the previous chart. The time interval is the time that passes between one dot and the next, which is 0.10 s every time. The average velocity can be calculated using these values.

8. Calculate the remainder of the average velocities on the chart.

Time		$\bar{v}_{ave}$ Between Dots (cm/s)	Time when $\bar{v}_{ave}$ Occurred (s)
Dot	**(s)**		
First	0		
		10	0.05
Second	0.10		
		15	0.15
Third	0.20		
		20	0.25
Fourth	0.30		
		25	0.35
Fifth	0.40		
		30	
Sixth	0.50		
Seventh	0.60		
Eighth	0.70		
Ninth	0.80		

It is important to realize that each of these average velocities occurred at a time midway between each pair of dots. For example, the average velocity between the first dot (t = 0 s) and the second dot (t = 0.10 s) occurred midway between these two times (t = 0.05 s).

9. Calculate the remainder of the times when average velocity occurred.

Check your answers by turning to the Appendix, Section 3: Activity 2.

Step 4: Acceleration is the change in velocity over a time interval. Calculate the change in velocity by finding the difference between the average velocities.

10. Complete the chart by calculating the remaining values for change in velocity.

Time		$\vec{v}_{ave}$ Between Dots (cm/s)	$\Delta\vec{v}$ (cm/s)
Dot	(s)		
First	0		
		10	
Second	0.10		5
		15	
Third	0.20		5
		20	
Fourth	0.30		5
		25	
Fifth	0.40		5
		30	
Sixth	0.50		
		35	
Seventh	0.60		
		39	
Eighth	0.70		
		45	
Ninth	0.80		

Look closely at the first four dots on the tape.

The object is always speeding up. Its average velocity will be equal to its instantaneous velocity at the middle of each time interval (close to the X). The time interval between adjacent Xs is also 0.10 s! The changes in velocity that you calculated each occurred in 0.10 s.

Step 5: Calculate the average accelerations for each of the velocity changes.

For example, the first two average velocities changed from 10 cm/s to 15 cm/s in 0.10 s.

$$\bar{a}_{ave} = \frac{\Delta \bar{v}}{\Delta t} = \frac{5 \text{ cm/s}}{0.10 \text{ s}} = 50 \text{ cm/s}^2$$

11. Complete the following chart by calculating the remaining values for acceleration.

Time		$\Delta \bar{v}$ (cm/s)	Acceleration (cm/s^2)
Dot	(s)		
First	0	–	–
Second	0.10	5	50
Third	0.20	5	50
Fourth	0.30	5	50
Fifth	0.40	5	
Sixth	0.50	5	
Seventh	0.60	4	
Eighth	0.70	6	
Ninth	0.80	–	–

Step 6: Average out all of these acceleration values. You will find that the average acceleration is 50 cm/s^2 or 0.50 m/s^2.

Note: If the motion has a constant or uniform acceleration, the acceleration values will "jump around" some average value. If the acceleration values themselves show an increase or decrease, you have a changing acceleration – a very complex motion!

Check your answers by turning to the Appendix, Section 3: Activity 2.

The graphs of the motion that you've been analysing have been drawn for you.

Position vs. Time

Position (cm)

Time (s)

Average Velocity vs. Time

Average Velocity (cm/s)

Time (s)

Acceleration vs. Time
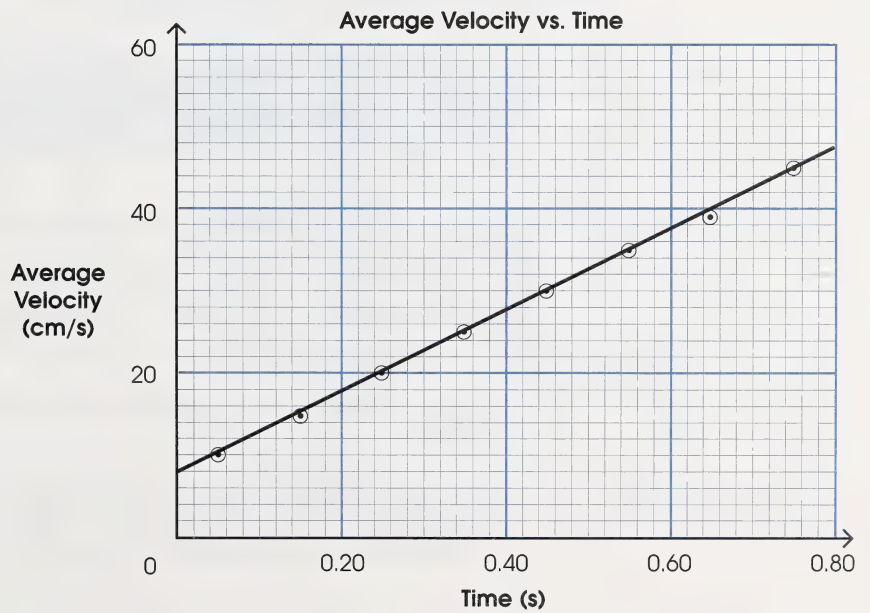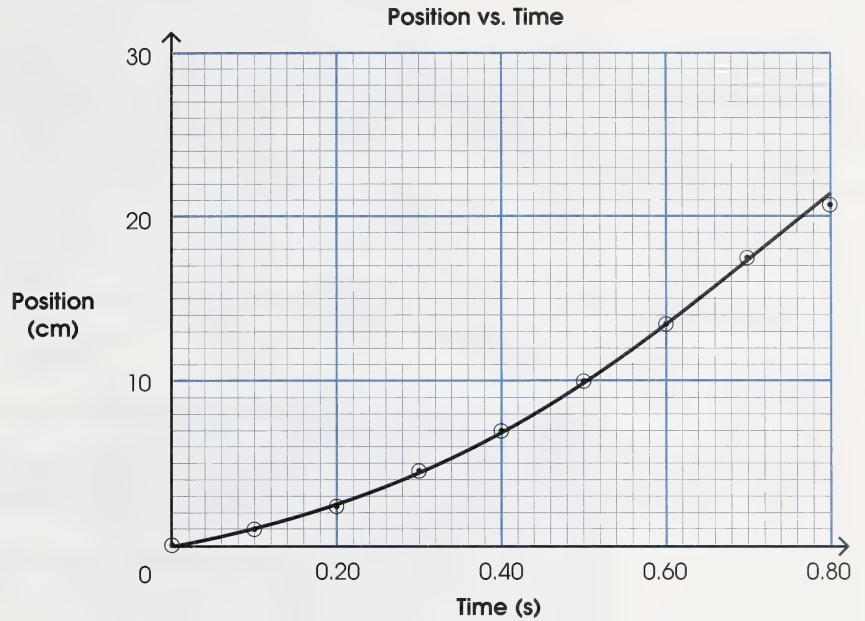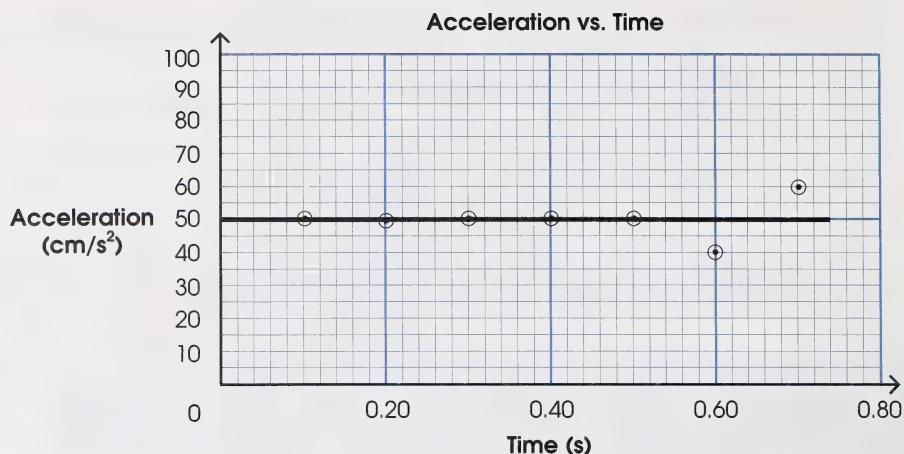
12. Why do you think the position-time graph is curved upwards?

13. Notice the placing of the dots on the average velocity-time graph. They are placed **in between** the intervals on the chart. Why?

14. The average velocity-time graph does not go through the origin. What does the y-intercept represent?

15. Calculate the slope of the average velocity-time graph. Does it equal the calculated acceleration as it should?

Check your answers by turning to the Appendix, Section 3: Activity 2.

The techniques developed here for analysing data from interval timers will be used throughout the course, so it is important that you have a clear understanding of how to do this. Since there is not enough space for very long and detailed data tables here, it is particularly important to remember the following things when using a more condensed approach.

- Each dot determines the position and time data from the start of the motion.

- The interval between dots determines the displacement and the average velocity of the motion. The average velocity occurs at a time midway between the time for each dot.

16. Here is another set of dots from an interval timer. These dots are 0.30 s apart. Note that the data charts have been condensed.
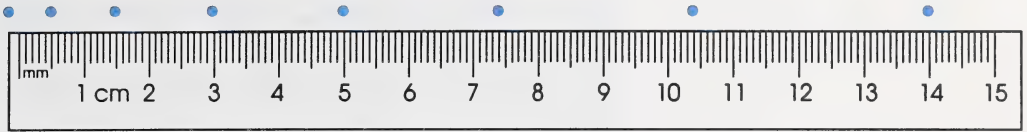
Science Skills

- [ ] A. Initiating
- [x] B. Collecting
- [x] C. Organizing
- [x] D. Analysing
- [ ] E. Synthesizing
- [ ] F. Evaluating

a. Measure the distance of each dot from the starting point and the displacement between adjacent dots.

Time (s)	Position (cm)	Displacement from Previous Dot (cm)
0	0	–
0.30	0.5	0.5
0.60	1.5	1.0

b. Calculate the average velocities for each of the time intervals, the differences between average velocities between time intervals, and the average acceleration for each of the velocity changes.

Time (s)	Average Velocity in an Interval (cm/s)	$\Delta \bar{v}$ (cm/s)	Acceleration (cm/s²)
0	–	–	–
0.30	1.67	–	–
0.60	3.33	1.66	5.53

c. Calculate the average acceleration.

d. Draw the position-time graph for this motion.
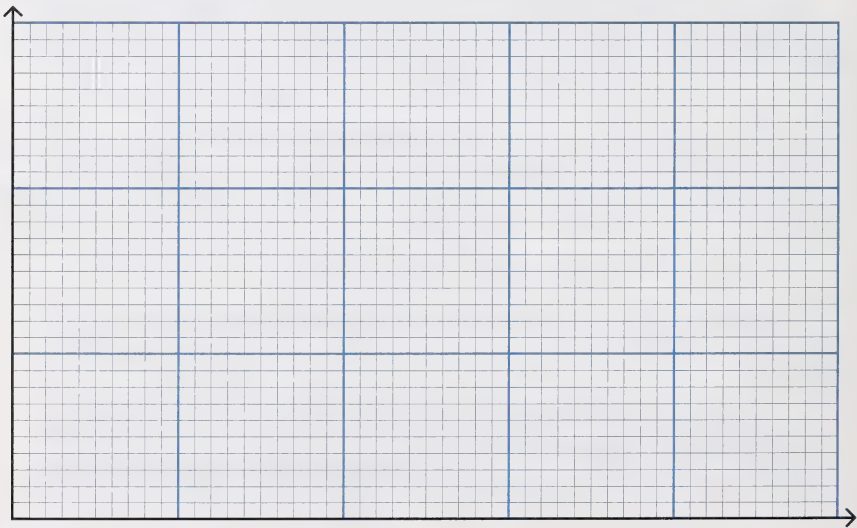
e. Draw the average velocity-time graph for this motion.
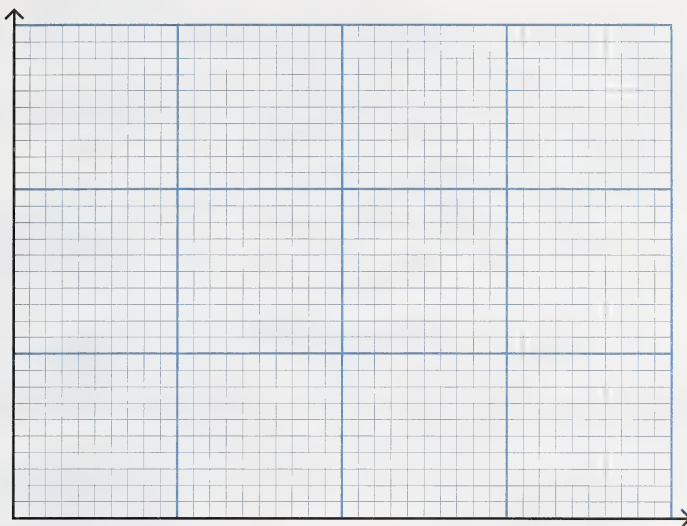
f. What is the slope of the average velocity-time graph?

g. Use the average velocity-time graph to find the initial velocity and the acceleration of this object.

Investigation: A Homemade Interval Timer

The sets of dots that you analysed were made with high-quality interval timers. In order to get useable results, you have to be confident that you are using accurate time intervals. In this investigation you will be asked to invent a device that will keep accurate time.

Science Skills

☑ A. Initiating
☐ B. Collecting
☐ C. Organizing
☐ D. Analysing
☐ E. Synthesizing
☐ F. Evaluating

Problem

17. Design a device capable of producing a regular time interval that can be measured.

18. Show how your timer can be used to chart the motion of an accelerating object. You will need to draw a labelled diagram of the timer and a labelled diagram of the setup that you would use in an experiment.

Check your answers by turning to the Appendix, Section 3: Activity 2.

Activity 3: Algebraic Treatment of Acceleration

You already know the equations that are used when you are studying uniform acceleration.

$$\vec{a} = \frac{\vec{v}_f - \vec{v}_i}{t}$$

$$\vec{v}_f = \vec{v}_i + \vec{a}t$$

$$\vec{v}_{ave} = \frac{\vec{v}_f + \vec{v}_i}{2}$$

You will now see what happens when these expressions are put together with $\vec{v}_{ave} = \frac{\Delta \vec{d}}{\Delta t}$.

To simplify the notation, the initial time for any application will be zero. As stated before, this allows the time interval to be represented by t instead of Δt. Similarly, if the initial position is also considered to be zero, the displacement for any time interval can be represented by $\vec{d}$ instead of $\Delta \vec{d}$. When the motion begins with the initial time and position both equal to zero, the average velocity can be written as follows:

$$\vec{v}_{ave} = \frac{\vec{d}}{t}$$

Sometimes equations can be combined to produce new equations. Look carefully at the following example.

$$\vec{d} = \vec{v}_{ave}\,t$$

$$\vec{v}_{ave} = \frac{\vec{v}_f + \vec{v}_i}{2}$$

Substitution

$$\vec{d} = \left(\frac{\vec{v}_f + \vec{v}_i}{2}\right)t$$

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PRINCIPLES AND PROBLEMS
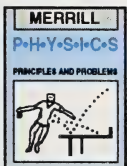
1. To see how this new equation can be applied, read page 71 of your textbook and do Practice Problems 14 and 15 on page 72.

Check your answers by turning to page 660 in your textbook.

Now you will see how to develop another new equation.

$$\vec{d} = \left(\frac{\vec{v}_f + \vec{v}_i}{2}\right) t \qquad \text{and} \qquad \vec{v}_f = \vec{v}_i + \vec{a}t$$

Since $\vec{v}_f$ equals $\vec{v}_i + \vec{a}t$,
put it into the other equation.

$$\vec{d} = \left(\frac{(\vec{v}_i + \vec{a}t) + \vec{v}_i}{2}\right) t$$

Collect like terms.

$$\vec{d} = \left(\frac{(2\vec{v}_i + \vec{a}t)}{2}\right) t$$

Split the fraction into two parts.

$$\vec{d} = \left(\frac{2\vec{v}_i}{2} + \frac{\vec{a}t}{2}\right) t$$

Multiply out the bracket.

$$\vec{d} = \vec{v}_i t + \frac{1}{2}\vec{a}t^2$$

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PRINCIPLES AND PROBLEMS
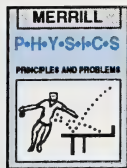
2. To better understand the origins of the equation that you just developed, read page 72 of your textbook. Then do Practice Problems 17 and 20 on page 74.

Check your answers by turning to page 660 in your textbook.

The equations developed so far in Physics 20 are listed.

Uniform Motion **Uniformly Accelerated Motion**

$$\bar{v} = \frac{\bar{d}}{t}$$ or $$\bar{d} = \bar{v}t$$ $$\bar{a} = \frac{\bar{v}_f - \bar{v}_i}{t}$$ or $$\bar{v}_f = \bar{v}_i + \bar{a}t$$

$$\bar{v}_{ave} = \frac{\bar{v}_f + \bar{v}_i}{2}$$

$$\bar{d} = \frac{(\bar{v}_f + \bar{v}_i)}{2}t$$

$$\bar{d} = \bar{v}_i t + \frac{1}{2}\bar{a}t^2$$

It is worth pointing out that in all of these equations, the vectors displacement ($\bar{d}$), velocity ($\bar{v}$), and acceleration ($\bar{a}$) are added or subtracted from each other, or multiplied by a scalar such as time. These vectors are not multiplied by each other. This is good news for you because you will learn how to add and subtract vectors in Module 2. However, the multiplication of a vector going east with a vector going northeast is actually a topic that most students study in college or university.

The next equation to be developed will be treated as a scalar. If vector symbols were used, it would imply that you need to know how to multiply two-dimensional vectors.

This equation is a little more complicated to develop than the others.

$$d = \left(\frac{v_f + v_i}{2}\right)t \qquad \text{and} \qquad v_f = v_i + at$$

Solve for t.

$$t = \frac{v_f - v_i}{a}$$

Now, replace t in the first equation with $\dfrac{v_f - v_i}{a}$ from the second equation.

$$d = \left(\frac{v_f + v_i}{2}\right)\left(\frac{v_f - v_i}{a}\right)$$

Multiply the fractions.

$$d = \frac{(v_f + v_i)(v_f - v_i)}{2a}$$

Multiply the brackets together.

$$d = \frac{v_f{}^2 - v_f v_i + v_f v_i - v_i{}^2}{2a}$$

Collect like terms.

$$d = \frac{v_f{}^2 - v_i{}^2}{2a}$$

Solve for $v_f{}^2$.

$$v_f{}^2 = v_i{}^2 + 2ad$$

To see how the textbook explains the origins of this equation, read from the bottom of page 74 through to the Example Problem on page 75. Note that the textbook does present this equation with vector symbols. Since the multiplication of vectors goes beyond the course, and the textbook doesn't explain this either, it is preferable for you to use the version of the equation presented in this module.

$$v_f{}^2 = v_i{}^2 + 2ad$$

Use this version when solving problems in activities, laboratory investigations, assignments, and tests.

3.   Do Practice Problems 21 and 22 on page 75 of your textbook.

Check your answers by turning to the Appendix, Section 3: Activity 3.

You may find all the equations that were developed to be a little overwhelming at first, but with practice you will start to feel more comfortable with them.
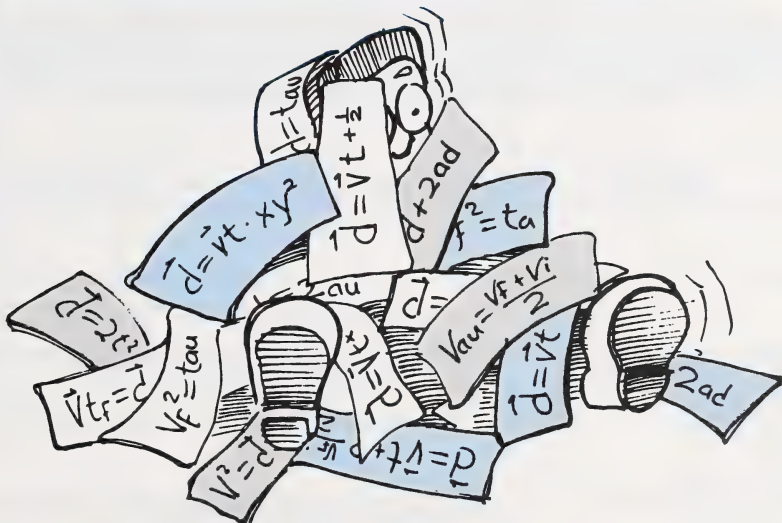
The following table summarizes the most important equations.

Uniform Motion	Uniformly Accelerated Motion
$\vec{v} = \dfrac{\vec{d}}{t}$ or $\vec{d} = \vec{v}t$	$\vec{a} = \dfrac{\vec{v}_f - \vec{v}_i}{t}$ or $\vec{v}_f = \vec{v}_i + \vec{a}t$
	$\vec{v}_{ave} = \dfrac{\Delta \vec{d}}{\Delta t}$
	$\vec{v}_{ave} = \dfrac{\vec{v}_f + \vec{v}_i}{2}$
	$\vec{d} = \dfrac{(\vec{v}_f + \vec{v}_i)}{2}t$
	$\vec{d} = \vec{v}_i t + \dfrac{1}{2}\vec{a}t^2$
	$v_f{}^2 = v_i{}^2 + 2ad$

4. It is a good idea to practise using all of these equations at once.

Try questions 10, 12, 16, and 20 on pages 83 and 84 of your textbook.

Acceleration Due to Gravity

You have solved a number of problems in this section involving the acceleration of aircraft, cars, and golf balls. However, the most common example of accelerated motion in your life occurs when objects fall through the air. If the objects fall without any restraints, it is called **free fall**.

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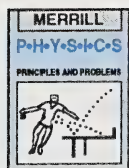
The acceleration of freely falling bodies is carefully explained on pages 76 and 77 of your textbook. Read those pages now and then attempt the following questions.

5. What symbol and number does the textbook use for the acceleration due to gravity?

6. Explain what the negative sign means in the value for $\bar{g}$.

7. What must be assumed to be true before $\bar{a}$ can be replaced with $\bar{g}$ in the equations developed earlier?

Check your answers by turning to the Appendix, Section 3: Activity 3.

8. Study the Example Problem on page 77 and then attempt Practice Problems 27, 29, and 31 on pages 79 and 80 of your textbook.

Check your answers by turning to page 661 in your textbook.

Investigation: Measuring the Acceleration of Gravity

Science Skills

☐ A. Initiating
☑ B. Collecting
☑ C. Organizing
☑ D. Analysing
☐ E. Synthesizing
☐ F. Evaluating

If air resistance can be ignored, and no other friction is present, objects in free fall are supposed to accelerate downward at a rate of 9.80 m/s^2. This acceleration is not an easy thing to measure because it is such a large rate. You are given four possible methods to measure g. Choose the method that you think will give the best results using the resources that are available to you.

Method A: Measure the time taken for an object to fall a known distance and calculate g from that.

Method B: Use an interval timer to track the motion of a falling object and calculate g like you did in Section 2.

Method C: Use a new mathematical tool and a pendulum to calculate *g*.

Method D: Use the experimental setup presented on the laser videodisc *Physics: Cinema Classics* and the freeze frame capabilities of the laser videodisc player to collect data from a television screen.

PATHWAYS

If you have access to a good water dropper, do Method A. If you have access to a good interval timer (maybe your own homemade one), do Method B. Anyone can do Method C. If you have access to the laser videodisc *Physics: Cinema Classics* and a laser videodisc player, do Method D.

Purpose

You will collect data and then calculate a value for the acceleration due to gravity.

Method A: Time to Fall a Known Distance

Materials

For this investigation you will need the following materials:

- a metre stick
- a water dropper
- a cake pan
- a clock with a second hand

Procedure

- Set your water dropper so that it drips steadily at a rate of more than
  one drip per second. Set the cake pan below the water dropper so that
  the drops make a loud noise when they land.

  Some examples of droppers are shown:

  buret   baby bottle
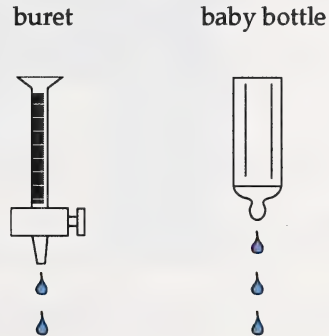
- Move the dropper so that it is about 1 m above the pan. Measure and
  record this distance.

- You should see a drop fall and then hear the sound of the drop on the
  pan. Adjust the rate of the drops so that you hear a sound at the same
  time as you see a drop fall. You are hearing the last drop landing at the
  same time as the present drop is falling.
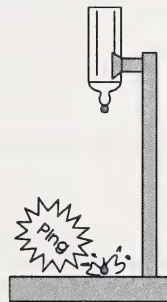
- Count the number of drops that fall in 10 s. Divide that number into 10 s to get the time between drops.

  (For example, 23 drops in 10 s is $\dfrac{10 \text{ s}}{23} = 0.43$ s between drops.)

9. Record your observations on the following chart.

	Distance for Each Drop (m)	Number of Drops in 10 s	Time Between Drops (s)
Trial 1			
Trial 2			

- You now know the time to fall a known distance. Now $d = v_i t + \dfrac{1}{2} g t^2$ and $v_i = 0$, so $d = \dfrac{1}{2} g t^2$ and $g = \dfrac{2d}{t^2}$.

  Calculate g using this last equation.

- Repeat the procedure with a slightly different distance between the water dropper and the pan.

  Find the average value of your measurements of g.

10. Calculate a value for g for each trial.

	$g = \dfrac{2d}{t^2}$ (in m/s^2)
Trial 1	
Trial 2	
Average Value of g	

11. It takes less than 0.5 s for the drops to fall 1 m. Can you accurately measure this amount of time with a stopwatch?

12. Is your value for g in the right range? How good is this experiment? Point out any possible sources of error.

End of Method A

Check your answers by turning to the Appendix, Section 3: Activity 3.

Method B: Using an Interval Timer

Materials

You will need the following materials for this experiment:

- timer
- paper tape
- weight
- ruler

Procedure

- Clamp the timer so that you can drop the weight attached to the tape vertically. The tape will fall through the timer.

Note: If your timer is not portable, drop the weight off the edge of a table instead.
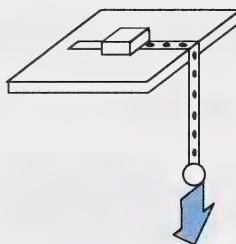
- Measure the distances between successive dots. Start wherever you are sure you can measure the distance (where the dots do not run together).

Start here

- Analyse the dots as you did in Section 2 of this module. You must find the average speed in each interval, the change in speed from one interval to the next, the acceleration between intervals, and the overall average acceleration.

13. Record your observations and complete the calculations in the following charts:

Length of time intervals: _____

Time (s)	Distance from Beginning (cm)	Distance from Previous Dot (cm)

Time (s)	Average Speed in an Interval (cm/s)	Δv (cm/s)	Acceler-ation (cm/s^2)
Overall Average Acceleration			

14. Was your value for g in the right range? Can you think of any sources of error in this experiment?

End of Method B

Check your answers by turning to the Appendix, Section 3: Activity 3.

Method C: Using a Pendulum

simple pendulum – in theory, a massless string that supports a sizeless mass. It swings by the action of gravity.

A simple pendulum is a weight hanging on a string that swings back and forth by the action of gravity. If a pendulum is set swinging at a small angle, it has a kind of motion called simple harmonic motion. This motion is analysed in Module 4. The period of time that a pendulum takes to make one complete swing (there and back again) is given by the following equation.

$$T = 2\pi\sqrt{\frac{l}{g}}$$

← Length of pendulum in metres

← Acceleration due to gravity

↑ Time for one complete swing

This equation will be explored in Module 4. Solving for g gives you this next equation.

$$g = \frac{4\pi^2 l}{T^2}$$

Materials

You will need the following materials for this investigation:

- mass
- string
- fastener
- metre stick
- clock with second hand (or stopwatch)

Procedure

- Design and make a simple pendulum. You need a mass, a string, and a way to fasten the pendulum to a support.

    Note: The mass should be small and heavy and the string should be light and strong.

- Measure and record the length of your pendulum. Measure to the centre of gravity of your mass. If the mass is symmetrical, the centre of gravity is at the centre of the mass.

- Set the pendulum swinging. Pull it out to a small angle (no more than 20° from vertical). Time how long it takes to swing 30 times. Longer pendulums will swing for 5 min or more. Remember that one swing is counted as a forward and back again motion.

- Divide the total number of swings into the total time to get the time for each swing.

- Build another pendulum with a different length and repeat these steps. Find your average values for g.

15. Record your observations in the following chart.

	Length (m)	Time for 30 swings (s)
First Pendulum		
Second Pendulum		

16. Complete the following calculations.

    a. Calculate the time for one swing for each pendulum.

    b. Calculate g for each pendulum.

    c. Calculate the average value for g.

17. How close are you to the theoretical value of g? Are you in the right range? Can you suggest a way to make this experiment more accurate?

End of Method C

Method D: Using a Laser Videodisc Recording of a Falling Bowling Ball

Materials

You will need the following materials for this investigation:

- the laser videodisc called *Physics: Cinema Classics*
- a laser videodisc player

If your laser videodisc does not have a bar code reader, enter the frame number(s) given in the icons.

Procedure

Load the laser videodisc called *Physics: Cinema Classics* Side A, into the laser videodisc player and press "play". Use the bar code reader to view the short video of a bowling ball being dropped.

Frames 27688 – 27712

You can see that the bowling ball drops at a rapid rate, making data collection difficult. To solve this problem, you will collect data with a sequence taken from a high-speed camera which filmed the bowling ball at an astonishing 3415 frames per second.

18.   How much time would elapse between each frame?

Check your answers by turning to the Appendix, Section 3: Activity 3.

The high-speed camera will isolate the motion of the bowling ball as it passes the 1-m, 2-m, 3-m, and 4-m mark as it falls.

Bowling ball

0 m ─────────────●─────────────

1 m ──────────────────────────

2 m ──────────────────────────

3 m ──────────────────────────

4 m ──────────────────────────

Frame 27721
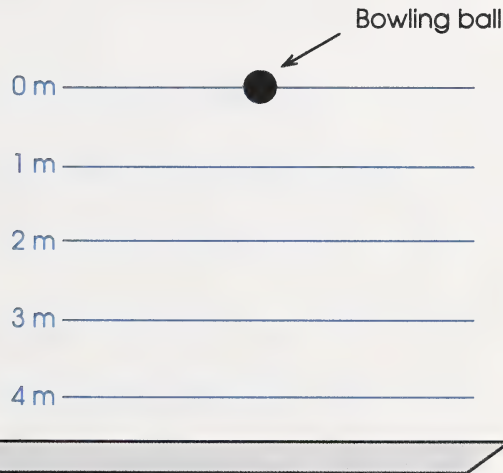
The sequence will provide a detailed view of the motion in a 20-cm region centered on each metre of the fall. Use the bar code reader to see what this would look like for the first 1 m of the fall.

Frame 27722

You will be using the step function of the laser videodisc player to watch the ball fall through the 20-cm region around each metre of its fall. To see this for the 1-m region, use the bar code reader and repeatedly touch the "step" key until the bowling ball is shown to be moving.

Example

When the centre of the ball crosses the centre of the top line, record that frame number.

43(27736) —— Record this number.

1m —
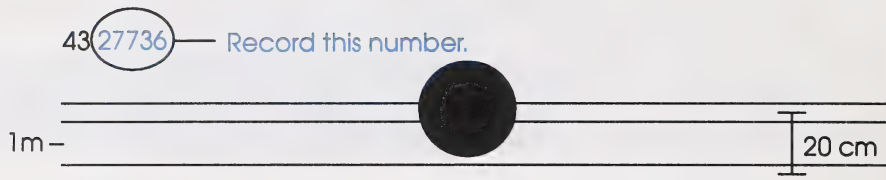
20 cm

When the centre of the ball crosses the centre of the bottom line, record that frame number.

43(27888) —— Record this number.

1m —
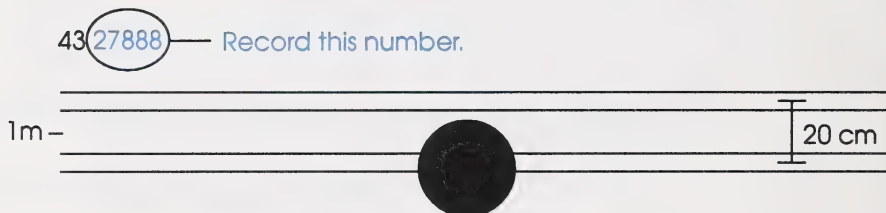
20 cm

19. How long did the bowling ball take to travel the 20 cm in the example?

20. What was the speed of the ball at the 1-m mark in the example?

21. The initial speed of the bowling ball was zero. Use this fact and your value for the speed of the ball after falling 1.0 m to calculate a value for g from the example.

22. Use the bar code reader and the step function on your laser videodisc player to gather your own data for the bowling ball as it falls through each metre marking. Record your data beside each bar code in the following chart.

Number of Frames for the Ball to Fall Through 20 cm (frames)	Time for the Ball to Fall 20 cm (s)	Speed of the Ball at the Metre Mark (m/s)	Value for g (m/s²)

Frame 27722

Frame 27914

Frame 28069

Frame 28217

What is the average value for g?

23. How close are you to the theoretical value? Can you suggest how this experiment could be made more accurate?

End of Method D

Check your answers by turning to the Appendix, Section 3: Activity 3.

No matter which method you chose for finding g, you were asked how close you came to the theoretical value. The value of g here in Alberta is $9.81 \, \text{m/s}^2$.

percent error – the error compared to the known value and expressed as a percent

When a scientist is asked how close an experimental value is to a theoretical value, the answer is given as a **percent error**. The following example will show you how to calculate a percent error.

Example

Suppose you got $9.68 \, \text{m/s}^2$ for g. How far from $9.81 \, \text{m/s}^2$ are you?

Find the difference between the numbers and express it as a positive number. This will give you the **error**.

error – how far from a known value a result is

$$\left| \left(9.81 \ \text{m/s}^2 \right) - \left(9.68 \ \text{m/s}^2 \right) \right| = 0.13 \ \text{m/s}^2$$

How big is this error compared to $9.81 \, \text{m/s}^2$? Express this as a percent.

$$\frac{0.13 \, \text{m/s}^2}{9.81 \, \text{m/s}^2} \times 100\% = 1.3\%$$

The percent error is 1.3%. That's a good value!!

Here is the general equation used to calculate percent error.

$$\text{percent error} = \frac{\left| \text{experimental value} - \text{theoretical value} \right|}{\text{theoretical value}} \times 100\%$$

24. Calculate your percent error for this investigation.

25. Suppose someone got 10.61 for g. Find the percent error for this value.

26. The equations developed in this section can be applied in a great variety of different situations. Do problems 1, 4, 8, 12, 14, and 16 from pages 690 and 691 of your textbook.
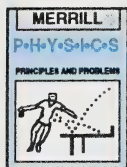
The equations that you have learned to apply in this module will be referred to again and again throughout the course. A worthwhile activity is to make a summary sheet of all the equations that you have used in this module. Be sure to leave room for equations from future modules because eventually your summary sheet will contain all of the equations from the whole course. Another good suggestion is to put the sheet in a clear plastic cover because it will be used often.

27. Begin your summary sheet by summarizing the important equations used in this module.

Check your answers by turning to the Appendix, Section 3: Activity 3.

Follow-up Activities

If you had difficulties understanding the concepts in the activities, it is recommended that you do the Extra Help. If you have a clear understanding of the concepts, it is recommended that you do the Enrichment.

Extra Help

The most important ideas from this section concern the meaning of acceleration.

- Acceleration is a change of velocity in a period of time.

- Velocity can change by speeding up, slowing down, or changing direction.

- Calculate acceleration by finding the change in velocity and dividing it by the time taken.

1. A bike starts at rest and speeds up to 15 m/s in 6.0 s. Find the acceleration by using the following steps:

   - Calculate the change in velocity.
   - Calculate the time taken.
   - Calculate the acceleration.

2. A car slows down from 85 km/h to 40 km/h in 9.0 s. What is its acceleration?

3. One way to measure acceleration is by watching the trail of an accelerating object and measuring how far it goes in some time interval. The following tape shows the position of an accelerating ball at 0.5-s intervals. Distances are in metres.
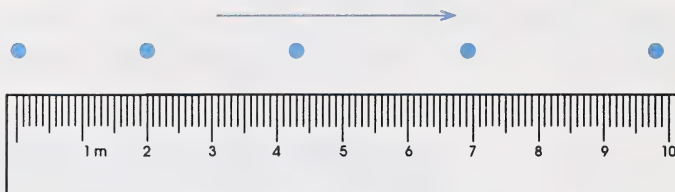
a. Record the displacement of the ball for each interval. Remember that the interval is the space **between** the dots.

	Displacement (m)
Interval 1	
Interval 2	
Interval 3	
Interval 4	

b. Average velocity is the displacement over a period of time. Calculate the average velocities for each time interval. The first one is done for you.

	Average Velocity (m/s)
Interval 1	$\bar{v}_{ave} = \dfrac{\Delta \bar{d}}{\Delta t} = \dfrac{+2.0\,m}{0.5\,s} = 4.0\,m/s$
Interval 2	
Interval 3	
Interval 4	

c. Calculate the change of velocity between the first and second intervals, the second and the third intervals, and the third and the fourth intervals.

d. Calculate the accelerations for the intervals. The first is done for you.

	Acceleration (m/s²)
Interval 1 to Interval 2	$\dfrac{\Delta \bar{v}}{t} = \dfrac{+0.6\,m/s}{0.5\,s} = 1.2\,m/s^2$
Interval 2 to Interval 3	
Interval 3 to Interval 4	

e. What is the average acceleration of this ball?

Check your answers by turning to the Appendix, Section 3: Extra Help.

Acceleration can be represented graphically. The meanings of acceleration graphs extend from those for uniform motion.

The slope of this graph is velocity.

Displacement vs. Time

d

t

The slope of this graph is acceleration.

Velocity vs. Time

The area under this graph is the change in position, or the displacement.

v

t

Acceleration vs. Time

The area under this graph is the change in velocity.

a

t

4. a. Calculate the acceleration of the moving object.

Velocity (m/s)

10

5

0

10   20   30

Time (s)
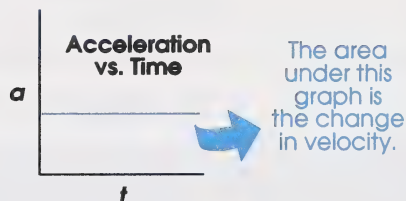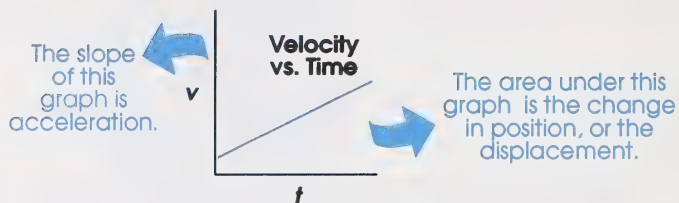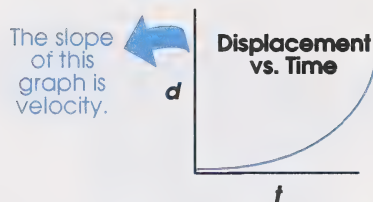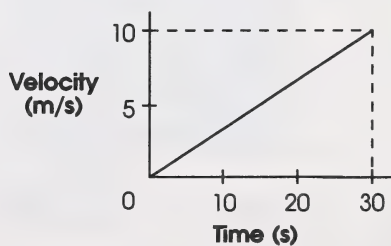
b. What is the displacement during the 30 s shown in this graph?

5. Describe the kind of motion occurring in each section of the following graph. Calculations may be required to completely describe each section.
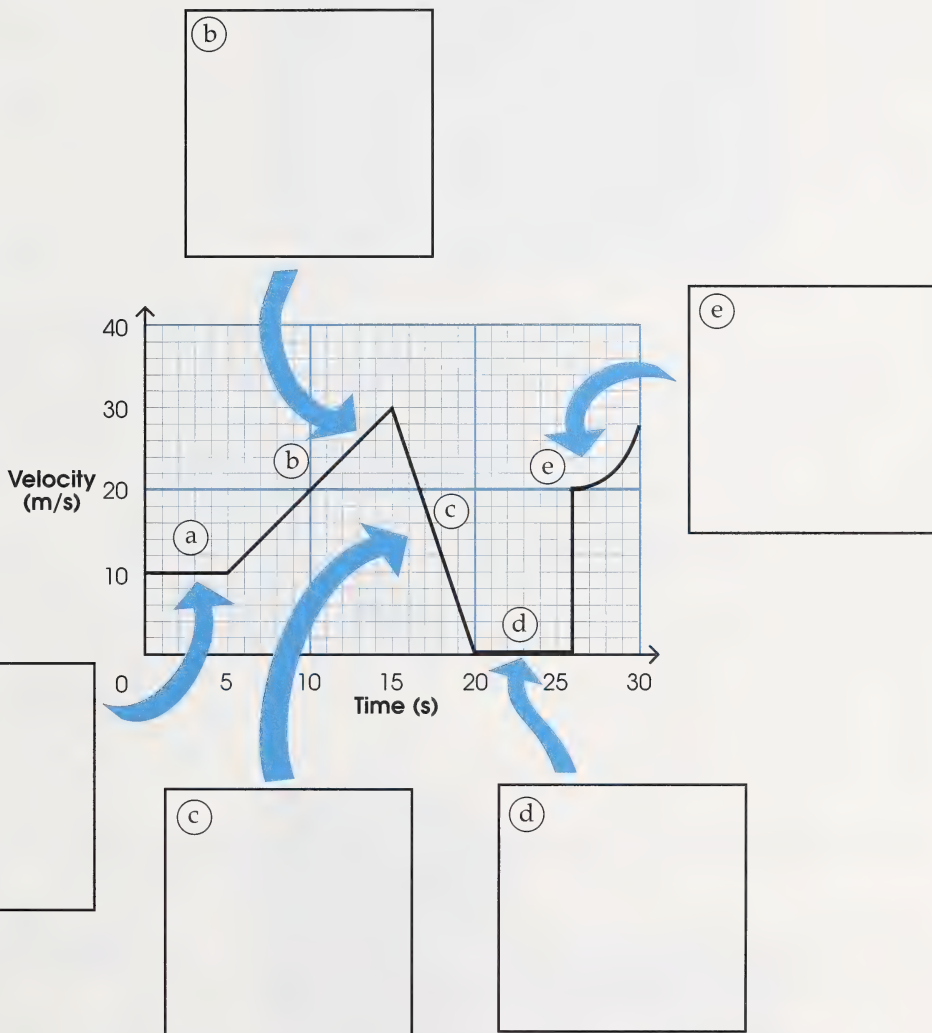
Once the meaning of acceleration is understood, the next task is to apply that understanding by solving problems. All those equations! They can overwhelm you. Here is a way to look at them that may help.
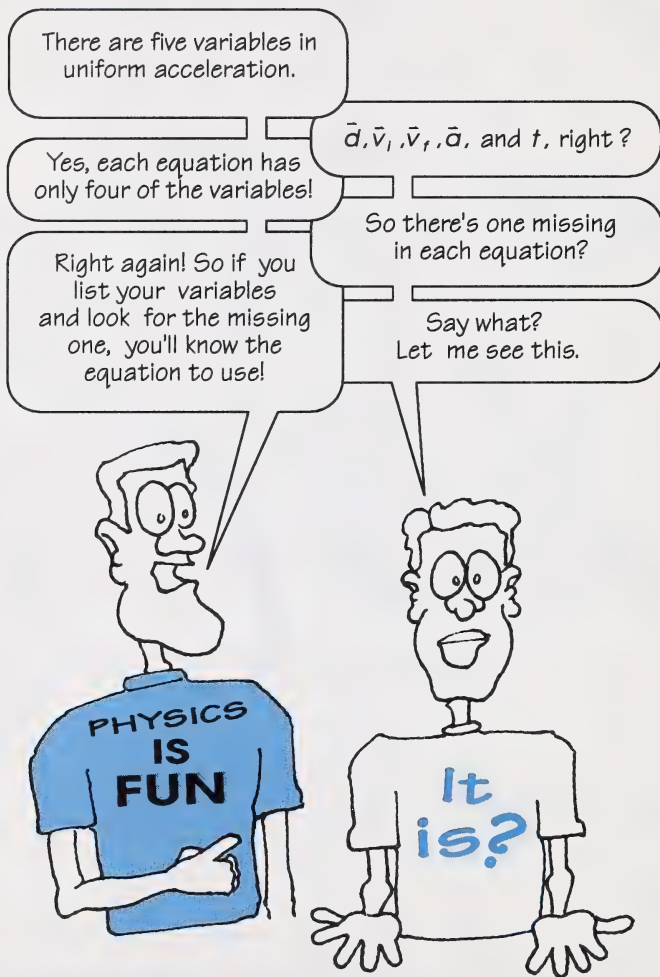
Equation	Missing Variable
$\vec{v}_f = \vec{v}_i + \vec{a}t$	d
$\vec{d} = \left(\dfrac{\vec{v}_f + \vec{v}_i}{2}\right)t$	a
$\vec{d} = \vec{v}_i t + \dfrac{1}{2}\vec{a}t^2$	v_f
$v_f^2 = v_i^2 + 2ad$	t

Example

A car slows from 45 m/s to 20 m/s in 30 s. How far did it go while doing this?

$\vec{d} = ?$ $\leftarrow$ Solve for this one.

$\vec{a}$ $\leftarrow$ This is the missing one!

$\vec{v}_f = 20$ m/s

$\vec{v}_i = 45$ m/s

$t = 30$ s

Which equation has no acceleration in it? Use the appropriate equation to solve the problem.

$$\vec{d} = \left(\frac{\vec{v}_f + \vec{v}_i}{2}\right)t$$

$$\vec{d} = \left(\frac{(+20\text{ m/s}) + (+45\text{ m/s})}{2}\right)30\text{ s}$$

$$= 9.8 \times 10^2 \text{ m}$$

The car went 9.8×10^2 m.

Example

A rock is dropped off a bridge that is 45 m high. How long will it take to hit the water?

$$\vec{d} = -45 \text{ m}$$

$$\vec{v}_i = 0$$

$$\vec{v}_f \qquad \leftarrow \qquad \text{This is the missing one!}$$

$$\vec{a} = \vec{g} = -9.8 \text{ m/s}^2$$

$$t = ? \qquad \leftarrow \qquad \text{Find this one.}$$

Note: $\vec{d}$ and $\vec{g}$ are both called negative since they both are in a downward direction.

What equation has no final velocity in it?

$$\vec{d} = \vec{v}_i t + \frac{1}{2}\vec{a}t^2$$

You can solve for any of the four variables in this equation. In this case, solve for time.

$\vec{v}_i = 0$ and $\vec{d} = \frac{1}{2}\vec{g}t^2$

$$t = \sqrt{\frac{2\vec{d}}{\vec{g}}} = \sqrt{\frac{2(-45 \text{ m})}{-9.80 \text{ m/s}^2}} = 3.0 \text{ s}$$

The rock takes 3.0 s to hit the water.

6. An airplane accelerates on a runway from rest to 95 m/s and takes off. If the airplane used 450 m of runway to do this, find its acceleration. Use the technique outlined in the last two examples.

7. You are running at 6.2 m/s when you remember that you forgot something. You skid to a stop at a rate of -2.5 m/s^2. How long did this take?

Check your answers by turning to the Appendix, Section 3: Extra Help.

Enrichment

Do any **two** of the following questions.

1. A strobe photo is like a set of dots from an interval timer. On page 76 of your textbook there is a photo of a falling ball. Use this image to get an acceleration value for the ball.

    • You will not get anywhere near 9.80 m/s^2 because the photo is not reproduced to the correct scale.

    • Something seems very wrong! Can you find out what?

    a. Create a chart of positions, displacements, and times. Consider the bottom of the first ball to be the reference point.

    b. Create a chart of average velocities, changes in velocities, and accelerations.

    c. What seems to be wrong?

Check your answers by turning to the Appendix, Section 3: Enrichment.
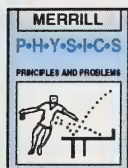
2. If you look closely at the equations from this section, you will notice that each equation is missing a variable. You should also notice that all of the equations include an initial velocity. The following set of equations is incomplete. Another equation can be developed by manipulating these two equations. Your job is to develop the missing equation.

$$\vec{v}_f = \vec{v}_i + \vec{a}t$$

$$\vec{d} = \left(\frac{\vec{v}_f + \vec{v}_i}{2}\right)t$$

Begin by manipulating the first equation to solve for $\vec{v}_i$. Then substitute this value for $\vec{v}_i$ into the second equation.

3. Do problems 25 and 28 from pages 84 and 85 of your textbook. These problems should be quite challenging.

MERRILL
P•H•Y•S•I•C•S
PRINCIPLES AND PROBLEMS
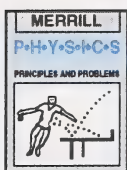
Check your answers by turning to the Appendix, Section 3: Enrichment.

Conclusion

In this section you studied uniform acceleration both graphically and algebraically. You also got involved and measured acceleration yourself.

MODULE SUMMARY

This module has given you the opportunity to learn the vocabulary and mathematical representation of the basic forms of motion. If you were to watch someone fly down a steep water slide now, the words displacement, velocity, and acceleration would likely be a great aid in describing how they moved. You could even take measurements and then estimate values with simple calculations.

It is interesting to note that a charity held some years ago in Edmonton had professional football and hockey players competing to see who could go the fastest down the city's scariest water slide. The measurements and calculations to determine the highest velocity were all done electronically with a police radar gun.

The emphasis in this module was on describing the motion, not explaining why things move the way they do. Explanations of why things move will be explored in Module 2.

Appendix

Glossary

Science Skills

Activities

Extra Help

Enrichment

Glossary

absolute zero – the temperature at which molecular motion is at a minimum, the lowest possible temperature

acceleration – the ratio of an object's change in velocity to the change in time

accuracy – how close a measure is to the correct value

algebra – mathematics where letters take the place of numbers

area under a curve – the area between the curve and the x-axis, between specified points on the x-axis

average velocity – the change in position or the displacement in a particular time interval

best fit curve – the curve (or line) that tracks the general trend of some data on a graph

controlled variable – the variable that is held constant in an experiment

cosmology – the study of the origin of the universe

deceleration – the act of slowing down

direct relationship – This is described mathematically by $y \propto x$. Increases in x cause proportional increases in y.

error – how far from a known value a result is

frame of reference – the point of view of the observer

inverse relationship – This is described mathematically by $y \propto \dfrac{1}{x}$. Increases in x cause proportional decreases in y.

Kelvin temperature scale – a scale that begins at absolute zero and goes up, with each Kelvin the same size as one Celsius degree

kinetic energy – energy due to motion

manipulated variable – the variable that you change

metronome – an instrument that marks regular time intervals with audible ticks

order of operations – Some people remember the order of operations by memorizing BEDMAS.

- Brackets
- Exponents
- Division and Multiplication
- Addition and Subtraction

percent error – the error compared to the known value and expressed as a percent

phenomenon – some event that occurs

physics – the science that deals with the interactions of matter and energy

potential energy – energy that is stored and able to be used

precision – how many decimal places a measure has been taken to

responding variable – the variable that changes as a result of the manipulated variable

scalar – any measured quantity that has size (magnitude) only (no direction)

simple pendulum – in theory, a massless string that supports a sizeless mass. It swings by the action of gravity.

superconductor – a substance with zero resistance to electric current

uniform motion – motion with an unchanging velocity; moving in a straight line at a constant speed

vector – any measured quantity which has a size (magnitude) and a direction

Science Skills

A Framework for Scientific Problem-solving Skills

A. Initiating and Planning

- Identify and clearly state the problem or issue to be investigated.
- Differentiate between relevant and irrelevant data or information.
- Assemble and record background information.
- Identify all variables and controls.
- Identify materials and apparatus required.
- Formulate questions, hypotheses, and/or predictions to guide research.
- Design and/or describe a plan for research or to solve the problem.
- Prepare required observation charts or diagrams.

B. Collecting and Recording

- Carry out and modify the procedure if necessary.

- Organize and correctly use apparatus and materials to collect reliable experimental data.

- Accurately observe, gather, and record information or data according to safety regulations (e.g., WHMIS) and environmental considerations.

C. Organizing and Communicating

- Organize and present data in a concise and effective form (themes, groups, tables, graphs, flow charts, and Venn diagrams).

- Communicate data more effectively, using mathematical and statistical calculations where necessary.

- Express measured and calculated quantities to the appropriate number of significant digits and use appropriate SI units for all quantities.

D. Analysing

- Analyse data and information for trends, patterns, relationships, reliability, and accuracy.
- Identify and discuss sources of error and their effect on results.
- Identify assumptions, attributes, bias, claims, or reasons.
- Identify main ideas.

E. Connecting, Synthesizing, and Integrating

- Predict from data or information.

- Formulate further testable hypotheses supported by the knowledge and understanding generated.

- Identify alternatives for consideration.

- Propose and explain interpretations or conclusions.

- Develop theoretical explanations.

- Relate the data to laws, principles, models, or theories identified in background information.

- Answer the problem investigated.

- Summarize and communicate findings.

- Decide on a course of action.

F. Evaluating the Process or Outcomes

- Establish criteria to judge data or information.

- Consider consequences and perspectives.

- Identify limitation of the data, information, interpretations, or conclusions as a result of the experimental/research/project/design processes or methods used.

- Suggest alternatives and consider improvements to experimental technique and design.

- Evaluate and assess ideas, information, and alternatives.

Criteria for Assessing Scientific Problem-solving Skills

A. Initiating and Planning

Level 1	Level 2	Level 3	Level 4	Level 5
• Proposes a simple problem statement when initiated to do so	• Proposes a simple problem statement	• Proposes a problem to be investigated	• Clearly states the purposes and problem to be investigated	• Performs at a level beyond level 4
• Background information must be supplied	• Background information is supplied from teacher or student's own experience	• Background supplied by teacher, reference material, or student's own experience	• Prepares the necessary background information from references, research, discussion, and/or past experience	• This is characteristic of work done at the college or university level
• Identifies those things that change and those that stay the same	• Identifies variables and controls	• Identifies controls, manipulated variables, and responding variables	• Identifies the controls and variables	
• Guesses about the outcomes	• Makes "educated" guesses	• Makes a prediction and/or suggests a simple hypothesis	• Forms an appropriate hypothesis and prediction • Designs an investigation	
• Identifies simple materials and equipment to be used	• Identifies materials and equipment to be used • Is able to assemble simple apparatus	• Identifies the materials and equipment to be used • Assembles simple apparatus	• Identifies and names the materials and equipment to be used • Assembles and designs or modifies simple apparatus	
• Follows directions as provided	• Follows directions as provided • Is able to write simple procedural statements	• Develops and organizes a simple written procedure	• Designs and writes descriptions of procedures that are clear and detailed	
	• Prepares observation charts, tables, and diagrams as directed by the teacher	• Prepares observation charts, tables, diagrams, graphs • Performs calculations as outlined by the teacher	• Prepares observation charts, diagrams, and graphs • Performs necessary calculations	

B. Collecting and Recording

Level 1	Level 2	Level 3	Level 4	Level 5
• Follows a simple procedure	• Follows a simple procedure	• Follows a given procedure and is able to suggest modifications when asked to do so	• Follows a given procedure and modifies the procedure when necessary	• Performs at a level beyond level 4
• Correctly uses apparatus and materials as directed by the teacher	• Correctly uses apparatus and materials with little teacher assistance	• Correctly uses apparatus and materials with infrequent modification	• Consistently uses standard apparatus and materials correctly	• This is characteristic of work done at the college or university level
• Collects data using concrete, tangible objects	• Collects tangible objects • Carries out simple measurements	• Accurately collects data	• Accurately collects relevant data	
• Records data in sentence form or in simple charts that have been constructed	• Records data in numerical and non-numerical form • Is able to use and construct simple charts	• Records relevant data including the correct units with respect to measured data	• Records relevant data using the appropriate units	
• Is aware of safety and environmental concerns • Follows stated safety procedures	• Is aware of safety and environmental concerns • Follows stated safety procedures	• Shows appropriate safety and environmental concerns in the use, care, and maintenance of materials and apparatus	• Demonstrates appropriate standards of safety	
		• Is able to locate appropriate safety regulations • Actively participates in teacher-directed discussion of safety and environmental issues	• Is able to suggest modifications to procedures to minimize environmental damage	

C. Organizing and Communicating

Level 1	Level 2	Level 3	Level 4	Level 5
• Organizes data in sets of concrete objects	• Organizes data in sets of objects	• Organizes data in the form of sets, themes, and/or tables	• Organizes data accurately	• Performs at a level beyond level 4
	• Provides a basis for the organization of data sets • Constructs simple graphs to represent the data	• Provides a basis for and suggests alternatives for the organization of data • Is able to construct graphs and/or tables to represent the data	• Is able to represent data using appropriate graphs and tables	• This is characteristic of work done at the college or university level
	• Performs basic mathematical calculations	• Performs basic mathematical calculations	• Performs relevant and required mathematical calculations	
	• Identifies errors and inaccuracies with teacher assistance	• Identifies errors and discrepancies in data • Takes part in teacher-directed discussion of scientific inaccuracies	• Expresses measured and calculated quantities to precision	

D. Analysing

Level 1	Level 2	Level 3	Level 4	Level 5
• Correctly identifies patterns within the data	• Assesses patterns and trends that are conceptually presented by the data	• Assesses patterns, trends, and simple relationships	• Assesses patterns, trends, and relationships resulting from collected and manipulated data	• Performs at a level beyond level 4
• Identifies relationships with teacher assistance	• Identifies simple cause and effect relationships	• Identifies cause and effect relationships	• Identifies the sources of error in data collection and manipulation	• This is characteristic of work done at the college or university level
	• Identifies the sources of error in data collection and manipulation with teacher assistance	• Identifies the sources of error in data collection and manipulation	• Expresses accuracy qualitatively and/or quantitatively (percent difference), where applicable • Identifies the assumptions relating to measurement and/or analysis	
	• Identifies the effect of errors on results with teacher assistance	• Suggests amendments to procedures and/or data manipulation in order to rectify results	• Determines the reliability of the data	

E. Connecting, Synthesizing, and Integrating

Level 1	Level 2	Level 3	Level 4	Level 5
• Provides a simple but not necessarily appropriate answer to the problem investigated based on results obtained	• Provides a simple answer that is appropriate for the problem investigated and results obtained	• Provides an appropriate answer to the problem investigated based on results obtained	• Provides a qualified answer to the problem investigated	• Performs at a level beyond level 4
	• Attempts to relate results to knowledge that is not specifically related to scientific theories or laws	• Relates results to applicable theories and/or laws with teacher assistance	• Relates the data to laws, principles, models, or theories identified in background information and/ or in broader context	• This is characteristic of work done at the college or university level
			• Proposes and explains interpretations or conclusions • Develops theoretical explanations	

F. Evaluating the Process or Outcomes

Level 1	Level 2	Level 3	Level 4	Level 5
• Attempts to explain results to the problem investigated	• Attempts to explain results to the problem investigated	• Is able to explain the results obtained in light of the problem being investigated	• Evaluates the prediction and concepts	• Restricts, revises, or replaces an unacceptable scientific concept
	• Attempts to draw conclusions where applicable and when prompted	• Draws conclusions and attempts to explain them	• Draws conclusions and attempts to explain them	• Establishes criteria to judge the design, prediction, and concepts
		• Discusses the limitations of the data collected, interpretations, and/or conclusions	• Identifies the limitations of the data and information, interpretations, or conclusions, as a result of the design of the experiment, research, or project	• Considers consequences and perspectives • Evaluates assumptions and effects of bias
		• Discusses, when prompted, the validity of results • Discusses, when prompted, alternatives and/or improvements to the experimental design	• Suggests alternatives and considers improvements to experimental technique and design	• Evaluates the total investigation in terms of reliability and validity

Suggested Answers

Section 1: Activity 1

1.

Year		
2000		
1990	← 1987	98° above absolute zero is reached. US announces an effort to exploit this new field.
1980	1986	IBM scientists find a material that works at 30° above absolute zero. Other materials that worked up to 90° above absolute zero were found.
1970	← 1973	
1960	← 1957	A metal alloy is found to superconduct at 23° above absolute zero.
1950		A superconductivity theory is proposed by John Bardeen, Leon Cooper, and Robert Schrieffer.
1940		
1930		
1920		
1910	← 1911	Heike Kamerlingh Onnes discovers superconductivity.
1900		

2. Textbook question 1.1:

No. He was researching the resistance of mercury at very low temperatures. He was surprised to see the resistance suddenly drop to zero.

3. The first theory came 46 years after the discovery. Some possible reasons include the following:

- Atomic theory had nothing in it to predict this phenomenon or to explain it.
- The technology to map atomic crystals was not available to guide the theoreticians.

4. Once a new discovery is made, others want in on the race. A lot of prestige and pride can ride on a discovery this big.

5. You should have listed two of the following applications:

- giant magnets
- efficient motors and generators
- power transmission
- magnetic levitation trains
- nuclear fusion reactors
- pinpointing diseased tissues (MRI)

6. No. Since mercury works below 4.2 K, you need something colder than this to get it to its superconducting temperature. Liquid helium is at 4 K, so it can be used to make mercury superconduct.

7. Their superconductivity temperatures are above the liquifying point for nitrogen, so liquid nitrogen will work for them. Liquid nitrogen is less expensive than liquid helium.

8.

Comparing the Process Skills Model to the Methods of Scientists	
Similarities	Differences
Both sources mention that not all scientists use the same method because the society that they live in will influence how they proceed. The personality of the scientists will also have an influence.	The textbook specifically mentions luck, imagination, trial and error, educated guesses, and great patience. The module booklet stresses that many of the process skills extend beyond the field of science.

9. There are many possible answers to this problem. One example of each skill is shown here.

Illustrating Science Skills in a Redecorating Project	
Science Skill	**An Example of a Skill from Jill's Project**
Initiating and Planning	Jill decides on a colour scheme and decides which walls will be papered and which will be painted.
Collecting and Recording	Jill visits the paint store and gathers the brochures on paint colours and wallpaper patterns. She shops around for the best prices.
Organizing and Communicating	Jill prepares a chart showing which store had the best price for each of the materials. She shows her parents the chart and tells them how much it will cost.
Analysing	When the chart is examined closely, it is pointed out that Jill forgot to add in the GST, paint brushes, and wallpapering tools. Jill is over her budget.
Connecting, Synthesizing, and Integrating	While discussing the money problem with a friend, a new idea is suggested. Instead of using wallpaper, why not paint a mural right on the wall! Since paint is relatively cheap, this would save money. Jill contacts some friends from art class.
Evaluating the Process or Outcomes	After the paint has dried Jill invites some friends over to have a look. They decide that her new scheme was achieved within the budget.

10. a.

Level of Initiating and Planning	
Pierre	**Scott**
Level 2	Level 3

Pierre has a unique plan. However, when his initial plan fails, he does not have a method that gives him an answer to the nearest centimetre. A level 3 response would have involved a follow-up plan once the first one failed. Perhaps he could have looked for another blueprint.

A level 4 response would have all that a level 3 response does, but would include a very detailed list of contact people and confirmation from other sources that his expert advice is correct. Level 4 responses involve the student actively preparing, researching, and anticipating all the alternatives.

Scott's plan outlines a clear method that produces a result in centimetres.

A level 4 response would have considered some variables that Scott forgot about. Are all the blocks exactly the same size? Has the amount of mortar between the blocks been considered? Is the amount of mortar between the blocks consistent? A level 4 response would have included a detailed write-up that would account for all these other things.

b.

Level of Collecting and Recording	
Pierre	**Scott**
Level 2	Level 2
Pierre followed a simple procedure and recorded his answer.	Scott followed his procedure and carried out simple measurements.
A level 3 response would have involved modifications to his procedure so that his answer was expressed to the correct units.	A level 3 response would have been more accurate, accounting for the thickness of the mortar. This measurement would have been neatly recorded with the others.
A level 4 response would have involved collecting data from many sources. A level 4 response would show all of the height measurements on a clearly labelled chart.	A level 4 response would have involved taking the measurements of many bricks and sections of mortar. All of these values would be displayed on a clearly labelled chart with a value for average block height and average mortar thickness.

11. The answer to this problem may be best answered with another question. Who are you working for when you do your work in this course? You are working for yourself. It's your future that will depend upon leaving high school with the skills that will help to make you successful. When you answer a question in an Assignment Booklet, it is worthwhile to ask yourself, "How did I do?" because this causes you to assess where you need to improve your skills. The real benefit to you is that you will come to know yourself better and you will begin to take personal responsibility for your life-long learning.

12. a. As each assignment is returned, record your assessment and the teacher's assessment under the appropriate columns on the spreadsheet.

  b. The whole point of keeping track of all the assessments in one place is to promote growth in your abilities. The sheet will help you to keep track of improvements and areas requiring further attention.

  c. The spreadsheet is in the Module 8 Assignment Booklet to provide a little extra incentive to record the assessments. You will receive 10 marks on your last assignment for filling in this spreadsheet accurately and completely.

Section 1: Activity 2

1. 9

2. 2

3. 1

4. 8

5. 1.5

6. 160

7. $\dfrac{15}{11}$

8. 0.68

9. 0.32

10. 5.67

11. 375

12. 443

13. 7.46×10^{-4}

14. 3.75×10^{6}

15. 7×10^{9}

16. 2×10^{6}

17.

Quantity Measured	Standard Unit
length	metre
mass	kilogram
time	second
speed	metre/second

18. a.   17 000 m = **17** km

b.   2.54 cm = **0.0254** m

c.   4.6 g = **0.0046** kg = **4.6 $\times$ 10^{-3}** kg

d.   19.6 $\times$ 10^5 kg = **1960** t

e.   one day = **86 400** s = **8.64 $\times$ 10^4** s

f.   9000 s = **2.5** h

g.   615 nm = **6.15 $\times$ 10^{-7}** m

h.   405 μm = **4.05 $\times$ 10^{-4}** m

i.   12.0 MHz = **1.20 $\times$ 10^7** Hz

j.   22.8 GJ = **2.28 $\times$ 10^{10}** J

19. a.   1.05 m + 5 cm = **1.10** m

b.   600 g + 1.5 kg – 400 g = **1700** g

c.   2.5 cm $\times$ 3.6 cm $\times$ 9.1 cm = **81.9** cm^3

d.   100 m^3 ÷ 6.25 m = **16.0** m^2

e.   2.5 cm $\times$ 1.1 cm + .50 cm $\times$ 3.6 cm = 2.75 cm^2 + 1.8 cm^2 = **4.55** cm^2

20.   Answers to these problems are found on page 656 of your textbook.

21.   The person with smaller steps will take more steps. It takes more of the smaller steps to equal fewer of the larger steps.

22.   There are 3600 s in 1 h.

23. Answers to these problems are found on page 656 of your textbook.

Section 1: Activity 3

1. 6.23 cm + 18.6 cm = 24.83 cm = 24.8 cm

2. 0.0651 kg + 10.02 kg + 3.033 kg = 13.12

3.
$$
\begin{array}{r}
48.116 \text{ cm} \\
188.01 \text{ cm} \\
+ 496 \text{ cm} \\
\hline
732.126 \text{ cm} = 732 \text{ cm}
\end{array}
$$

4.
$$
\begin{array}{r}
387.9 \text{ kg} \\
- 116.81 \text{ kg} \\
\hline
271.09 \text{ kg} = 271.1 \text{ kg}
\end{array}
$$

5. 2.36 cm × 1.2 cm = 2.832 cm^2 = 2.8 cm^2

6. 9.81 m/s + 2.852 m/s = 3.44

7. 13.6 kg + 118.22 kg = 0.115

8. 1.1 cm × 2.3 cm + 6.8 cm × 11.55 cm = 81 cm^2

9. Precision indicates the number of decimal places in a measurement.

10. Accuracy indicates how close a measurement is to the actual value.

11. good accuracy, good precision ___c___
    good accuracy, bad precision ___a___
    bad accuracy, good precision ___b___
    bad accuracy, bad precision ___d___

12. Answers to these problems are found on page 657 of your textbook.

13. Statement 2 is correct. You can only be as good as your worst measurement.

14. Answers to these problems are found on page 657 of your textbook.

15. You must include the circled items in your graph.

Pressure vs. Depth
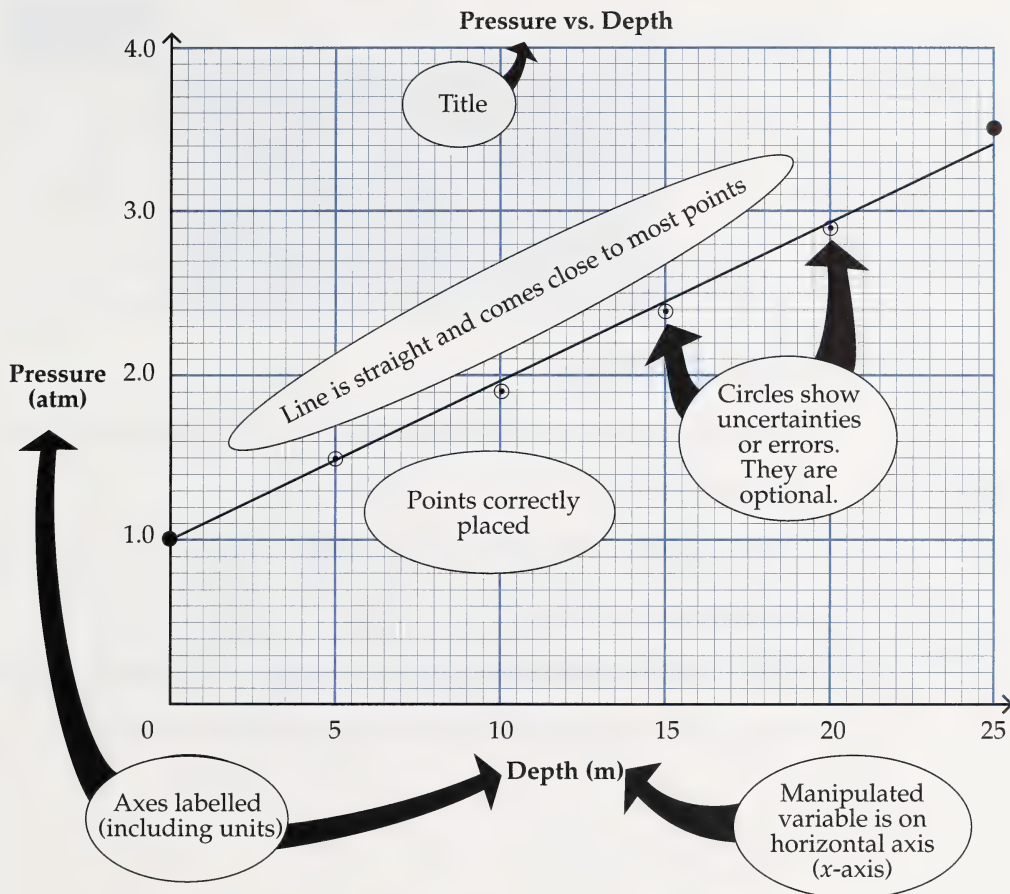
16. a. slope $= \dfrac{\text{rise}}{\text{run}} = \left(\dfrac{80 \text{ g} - 0 \text{ g}}{100 \text{ mL} - 0 \text{ mL}} \right) = 0.80 \text{ g/mL}$

   - Use the best fit line, not the points, to calculate the slope.
   - Use a large triangle to calculate the slope.

   b. The slope represents the density of alcohol.

   c. A direct relationship exists between the mass and volume of alcohol.

17. The graph is perfect. It follows all the rules.

	Check
Is the title correct?	✓
Are the axes correctly labelled? Do the labels include the correct measures and units?	✓
Are the scales easy to read?	✓
Are the points accurately placed?	✓
Has the best fit curve or line been drawn?	✓

18. Textbook question 16. a.:

   30 cm^3 of each substance have masses of about 90 g, 270 g, and 410 g.

   Textbook question 16. b.:

   100 g of each substance have volumes of about 7 cm^3, 11 cm^3, and 36 cm^3.

   Textbook question 16. c.:

   The steepness (slope) is the mass per unit volume or density of each substance.

19. Answers to these problems are found on page 657 of your textbook.

20. a. $i = prt$

   $$\frac{i}{pt} = \frac{prt}{pt}$$

   $$r = \frac{i}{pt}$$

   b. $A = \pi r^2$

   $$\frac{A}{r^2} = \frac{\pi r^2}{r^2}$$

   $$\pi = \frac{A}{r^2}$$

c. $V = \pi r^2 h$

$$\frac{V}{\pi h} = \frac{\pi r^2 h}{\pi h}$$

$$r^2 = \frac{V}{\pi h}$$

$$\sqrt{r^2} = \sqrt{\frac{V}{\pi h}}$$

$$r = \sqrt{\frac{V}{\pi h}}$$

d. $d = v_i t + \frac{1}{2} a t^2$

$$d - v_i t = v_i t + \frac{1}{2} a t^2 - v_i t$$

$$d - v_i t = \frac{1}{2} a t^2$$

$$2(d - v_i t) = \frac{1}{2} a t^2 \bullet 2$$

$$2(d - v_i t) = a t^2$$

$$\frac{2(d - v_i t)}{t^2} = \frac{a t^2}{t^2}$$

$$a = \frac{2(d - v_i t)}{t^2}$$

e. $v_f = v_i + at$

$$v_f - v_i = v_i + at - v_i$$

$$v_f - v_i = at$$

$$\frac{v_f - v_i}{a} = \frac{at}{a}$$

$$t = \frac{v_f - v_i}{a}$$

Section 1: Follow-up Activities

Extra Help

1. This is the usual order of the scientific process.
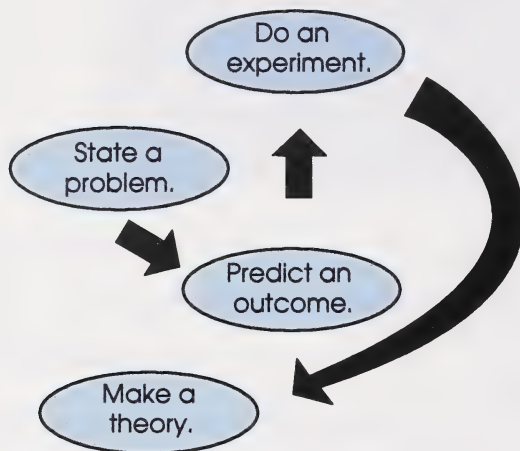
However, some huge discoveries in physics have followed this route!
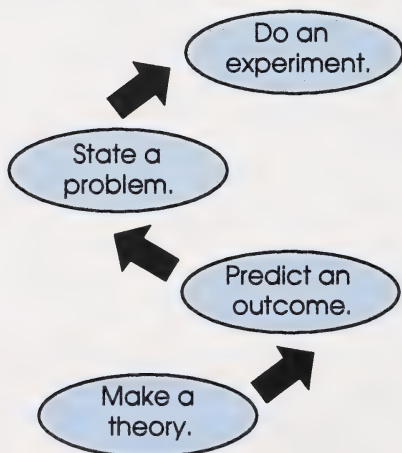
2. a. 15.57

   b. 3.69

   c. 0.474 22

   d. $\sqrt{244\ 441} = 494.4$ (rounded off)

   e. 2.75×10^{-9} (rounded off)*

   f. 481.5 (rounded off)

   g. 1 058 841 (rounded off)

   * Watch out for these small numbers. Your calculator may cut off numbers when displaying them in standard notation. Put this into scientific notation to be sure of it.

3. a. one metre = | 10^9 or a billion | nanometres

   b. one gram = | 100 | centigrams

   c. one kilohertz = | 1000 | hertz

   d. one millimetre = | 1/1000 or 0.001 | metres

   e. one hertz = | $1/10^6$ or 10^{-6} | Megahertz

4. a. 7.88

   b. 1.97

   c. 0.221

   d. 7.92×10^{22}

   e. 2.98

The graph did not have a title.

Length of Wire vs. Temperature

Length of wire (cm)

There were no units indicated. Length is measured in centimetres.

Temperature (°C)

There were no units indicated. Temperature is measured in °C.
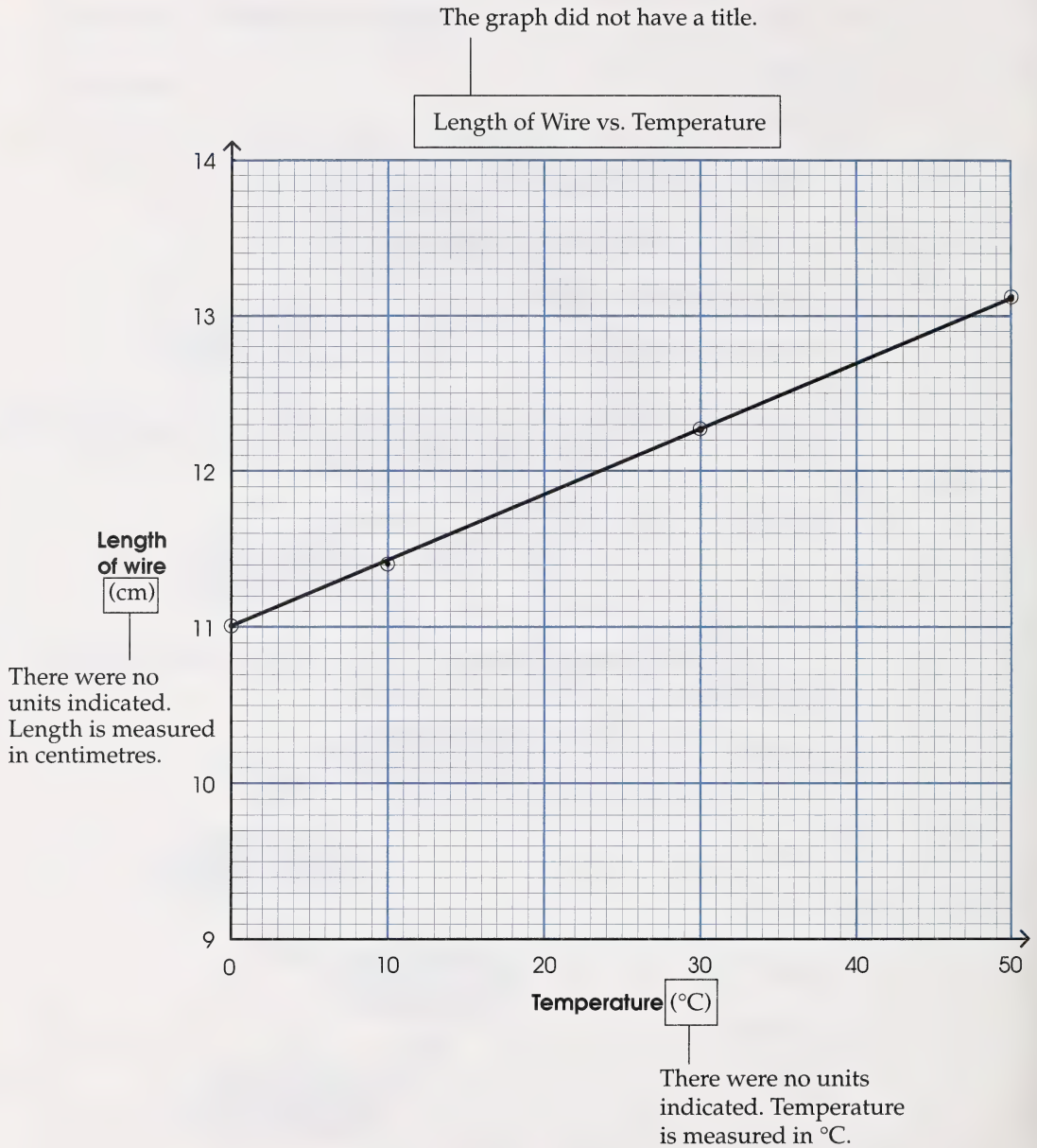
It is acceptable for the vertical axis to begin at 9 cm.

b. Yes, the graph is linear. It is a straight line.

c. No, it is not a direct relationship because the line does not pass through the origin.

d. The slope represents how much the length of the wire changes for each degree of temperature change.

e. $\text{slope} = \dfrac{\text{rise}}{\text{run}} = \dfrac{13.1 \text{ cm} - 11.0 \text{ cm}}{50.0°C - 0°C}$

$= \dfrac{2.1 \text{ cm}}{50.0 \, °C}$

$= 0.042 \text{ cm}/°C$

6. a. $v_f^{\,2} = v_i^{\,2} + 2ad$

$v_f^{\,2} - v_i^{\,2} = 2ad$

$d = \dfrac{v_f^{\,2} - v_i^{\,2}}{2a}$

b. You can use either of the following methods. You get the same answer with both methods.

Method 1

$\dfrac{ab}{c} = \dfrac{e^2}{f}$ Cross multiply.

$abf = ce^2$ Divide by e^2 and

$c = \dfrac{abf}{e^2}$ rearrange.

Method 2

$\dfrac{ab}{c} = \dfrac{e^2}{f}$ Take the reciprocal
of both sides.

$\dfrac{c}{ab} = \dfrac{f}{e^2}$ Multiply by ab.

$c = \dfrac{abf}{e^2}$

Enrichment

1. a.

Time (s)	E_k (J)	E_p (J)
0	0	610
1.0	29.0	580
1.5	68.0	550
2.0	120	490
2.5	190	420
3.0	270	340
3.5	360	240
4.0	480	130
4.5	600	0

Note: Since the data is given to three and four significant digits, your calculations should be rounded off to three significant digits throughout.

b. $E_k = \frac{1}{2}mv^2$

$$= kg \cdot \left(\frac{m}{s}\right)^2$$

$$= \frac{kg \cdot m^2}{s^2}$$

$$= J$$

The units for potential energy and kinetic energy are the same.

c.

E_p vs. Time
E_k vs. Time
Total $E_k + E_p$ vs. Time

Energy (J)

Time (s)

△ Potential Energy
▣ Kinetic Energy
⊙ Total Energy
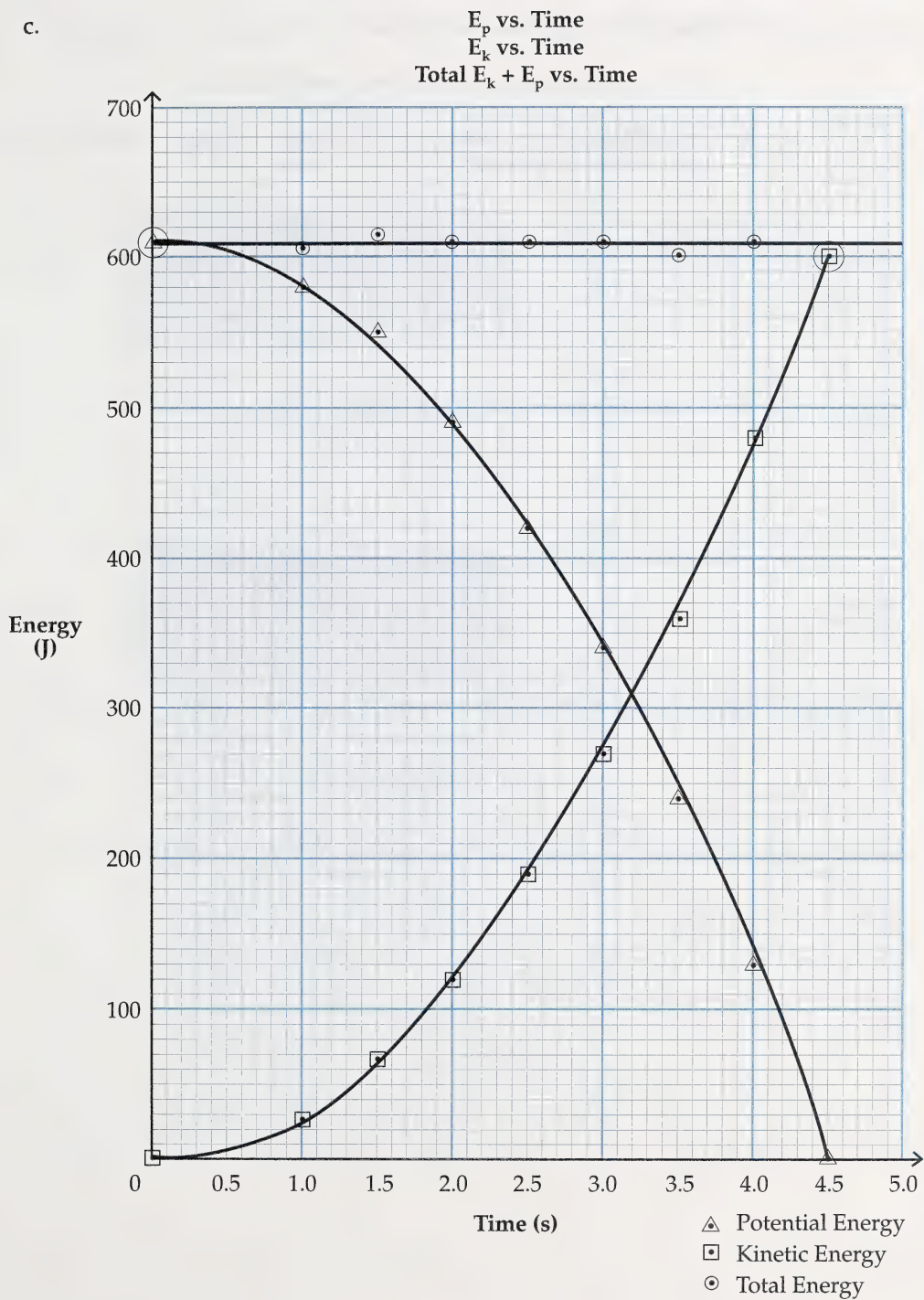
    d. The total energy is nearly constant.

    e. The kinetic energy comes from the potential energy.

2. a. The following data represents possible measurements. Answers will vary, depending on the condition of wire or wood used.

Sample Data for 14 Gauge Copper Wire	
Mass (g)	**Length (cm)**
1.6	8
Use the graph to predict this mass.	16
4.7	24

Sample Data for 2″ by 4″ Lumber	
Mass (g)	**Length (cm)**
170	10
Use the graph to predict this mass.	30
860	50

b. Two graphs are shown here. Answers will vary, depending on the available materials.

Sample Graph of Mass vs. Length for 14 Gauge Wire

The mass of the middle wire is estimated to be 3.1 g or 3.2 g using the graph.

Mass (g)

Length (cm)

Sample Graph of Mass vs. Length for 2" by 4" Lumber

Mass (g)

Length (cm)

This mass of the middle piece of wood is estimated to be 520 g.
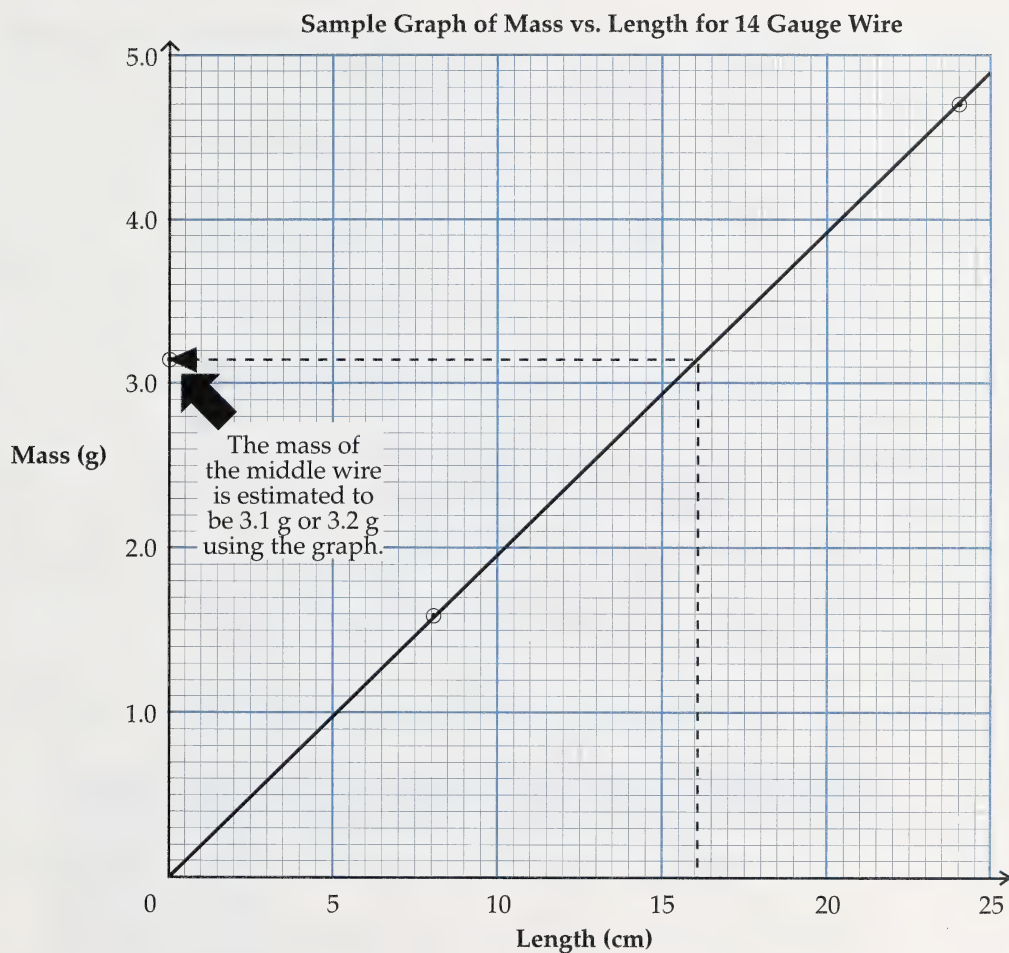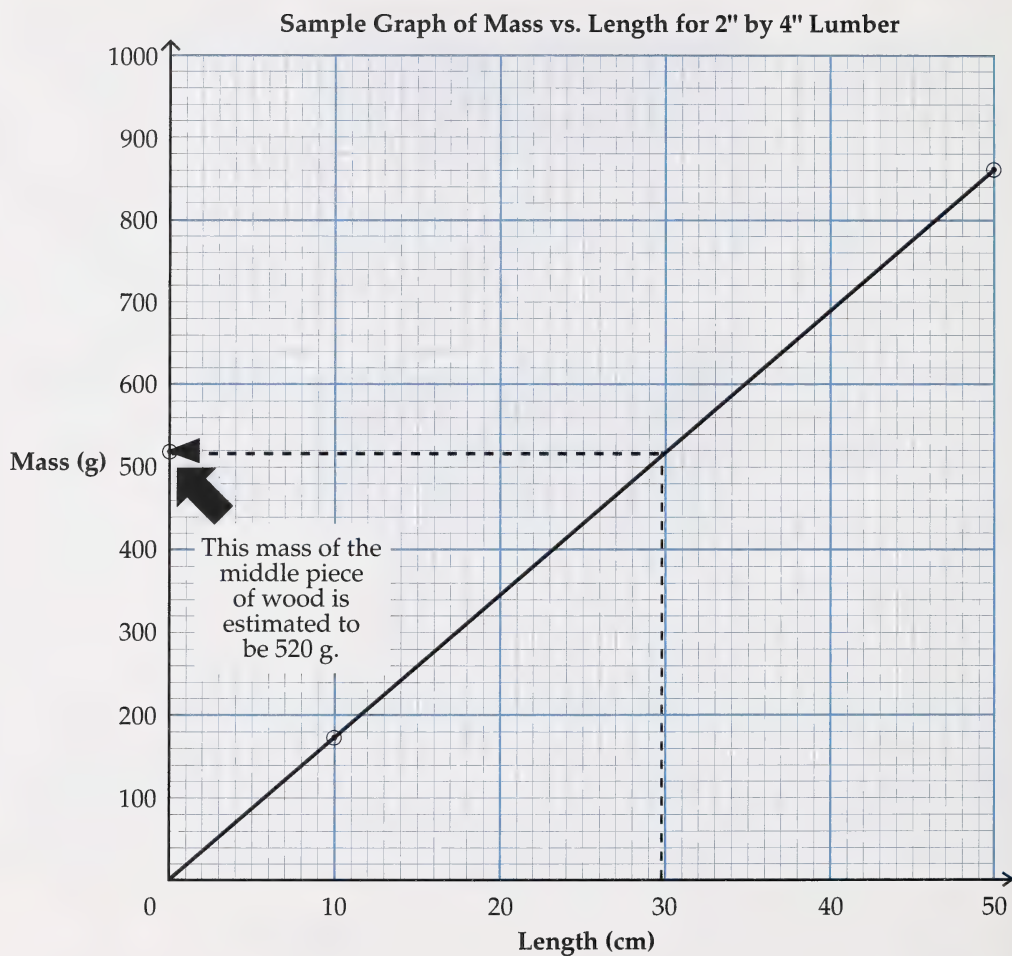
c.   Textbook question 1:

The line on the graph should pass through the origin because when the length is zero, the mass should also be zero.

Textbook question 2:

Use the sample graph for the 14 gauge copper wire.

$$\text{slope} = \frac{\text{rise}}{\text{run}}$$
$$= \frac{3.15\,\text{g} - 0\,\text{g}}{16.0\,\text{cm} - 0\,\text{cm}}$$
$$= 0.20\,\text{g/cm}$$

Use the sample graph for the 2″ by 4″ lumber.

$$\text{slope} = \frac{\text{rise}}{\text{run}}$$
$$= \frac{520\,\text{g} - 0\,\text{g}}{30\,\text{cm} - 0\,\text{cm}}$$
$$= 17.\overline{3}\,\text{g/cm}$$
$$= 17\,\text{g/cm}$$

Both slope calculations were rounded off to two significant digits since this was the least number of significant digits in the initial data.

Textbook question 3:

The slope gives the average mass per length.

Section 2: Activity 1

1.

Term	Meaning
reference point	the zero location or "home base" for some situation
position	how far and in what direction an object is from the reference point
distance	the separation between two points

2. reference point: vector (This is really technical, but it is a position.)

    position: vector

    distance: scalar

3. a. The reference point on the pirate's map is the large tree on Hangman's Beach.

    b. The position of the treasure is 38 paces north of the large tree. Since the position is a vector, it has magnitude (38 paces) and direction (north).

    c. Without a reference point the map would read as follows: Step off 38 paces straight north to find where the treasure is buried. Since no starting point is given, the treasure could be almost anywhere!

    d. If the map gave only a distance, it would read as follows: Begin at the base of the large tree on Hangman's Beach. Step off 38 paces to find where the treasure is buried.

    Since distance is not a vector, no direction is given, so you don't know which way to go.
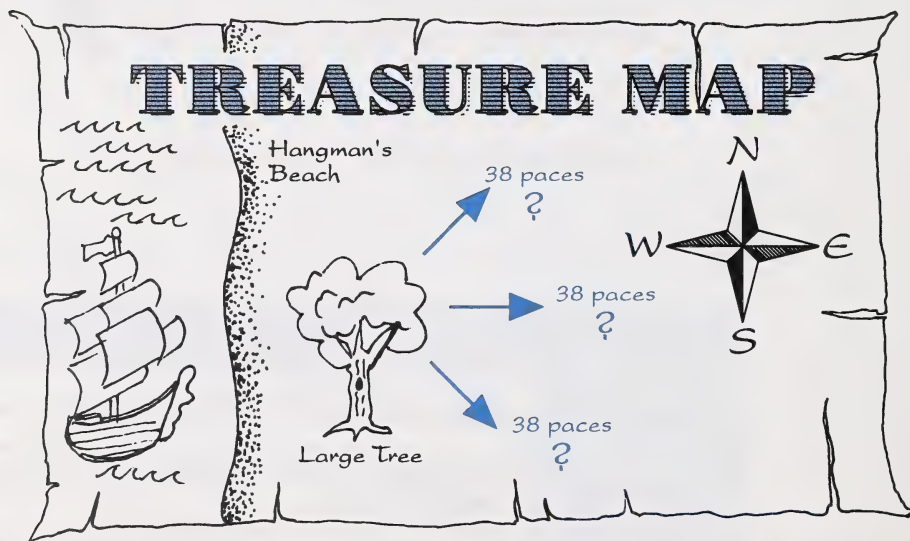
To find the treasure a person would have to dig at every place 38 paces from the tree. This would mean digging one very large circular trench at 38 paces from the tree!

4. Displacement is the change in position of an object. Displacement is given the symbol $\Delta \vec{d}$ (pronounced "delta d").

5. The average velocity of an object is the displacement divided by the change in time.

$$\vec{v}_{ave} = \frac{\Delta \vec{d}}{\Delta t}$$

6. a. $t_1 = 1.0$ s $\vec{d}_1 = 30$ m
   $t_2 = 2.0$ s $\vec{d}_2 = 35$ m

   displacement: $\Delta \vec{d} = \vec{d}_2 - \vec{d}_1$
   $$= 35 \text{ m} - 30 \text{ m}$$
   $$= +5 \text{ m}$$

   average velocity: $\vec{v}_{ave} = \frac{\Delta \vec{d}}{\Delta t}$
   $$= \frac{+5 \text{ m}}{1 \text{ s}}$$
   $$= 5 \text{ m/s}$$

   b. $t_1 = 2.0$ s $\vec{d}_1 = 35$ m
   $t_2 = 3.0$ s $\vec{d}_2 = 45$ m

   displacement: $\Delta \vec{d} = \vec{d}_2 - \vec{d}_1$
   $$= 45 \text{ m} - 35 \text{ m}$$
   $$= +10 \text{ m}$$

   average velocity: $\vec{v}_{ave} = \frac{\Delta \vec{d}}{\Delta t}$
   $$= \frac{+10 \text{ m}}{1.0 \text{ s}}$$
   $$= 10 \text{ m/s}$$

   c. Both the displacement and the average velocity of the car are zero between $t = 0$ s and $t = 1.0$ s.

7. They are moving in opposite directions.

8. a. The direction is changing, so this is not uniform motion.

    b. This motion has constant speed and direction, so it is uniform motion.

    c. The speed is increasing, so this is not uniform motion.

    d. This motion has constant speed and direction, so this is uniform motion.

9. The average speed was 300 km + 3 h = 100 km/h. The average velocity was 100 km/h north.

10. Speed and velocity will be the same for an object's motion when it is stopped. In this case, both values are zero.

11. Your results will differ from these, but the trends in the data should be the same.

    The following is a sample only.

	Time (s)		
	Time to Reach 10 m	Time to Reach 20 m	Time to Reach 30 m
Trial 1	2.0	4.1	6.2
Trial 2	1.6	3.3	4.7
Trial 3	3.1	6.7	10.7

12.

	Velocity (m/s)		
	Average Velocity over 10 m	Average Velocity over 20 m	Average Velocity over 30 m
Trial 1	10 m ÷ 2.0 s = 5.0 m/s	20 m ÷ 4.1 s = 4.9 m/s	30 m ÷ 6.2 s = 4.8 m/s
Trial 2	10 m ÷ 1.6 s = 6.3 m/s	20 m ÷ 3.3 s = 6.1 m/s	30 m ÷ 4.7 s = 6.4 m/s
Trial 3	10 m ÷ 3.1 s = 3.2 m/s	20 m ÷ 6.7 s = 3.0 m/s	30 m ÷ 10.7 s = 2.8 m/s

Note: Rounding to two significant digits is done here. If you're good at timing, you can use three significant digits.

13. Your results will be different from these. The following answers are based on the sample data.

    Trial 1: The velocity seems to be steadily slowing down.

    Trial 2: The velocity slows down and then speeds up! This kind of data is common and usually results from timing errors.

    Trial 3: The velocity is steadily slowing down.

14. No. You only know the average velocities at each measured distance.

15. You could measure at 5-m intervals (or 1-m intervals). The closer the intervals are, the more precisely you will know the details of the motion.

16. Friction will have caused any slowing-down effect. A smooth surface and a heavy ball will make the effect smaller.

17. Your results will likely be different from these, but some things should be similar. The following is a sample only.

Interval Number	Displacement from Previous Smear (cm)	Total Displacement from First Smear (cm)
1	11	11
2	13	24
3	10	34
4	12	46
5	11	57

18. The time between events is 0.28 s. This is a sample answer. Your answers may vary.

19. These calculations are based on the sample data from the previous two questions.

Interval Number	Total Time(s)	Average Velocity (cm/s)
1	0.28	11 cm + 0.28 s = 39 cm/s
2	0.56	24 cm + 0.56 s = 43 cm/s
3	0.84	34 cm + 0.84 s = 40 cm/s
4	1.12	46 cm + 1.12 s = 41 cm/s
5	1.40	57 cm + 1.40 s = 41 cm/s

20. Your results will differ from these. This answer is based on the sample data.

    For this data, the velocity is constant around 41 cm/s. The fluctuations are mostly caused by errors in placing your finger beside the marble accurately.

21. No. You only know the average velocity for the chosen time intervals.

22. You could choose a timer with shorter intervals. The shorter these intervals are, the more precisely you know the motion.

23. Friction will slow the marble down. A smooth table will keep this effect small. If the table is not level, the marble could also slow down.

Section 2: Activity 2

1.

The graph is linear. This means that ...	➡	the change of position is the same each second.
The graph doesn't go through the origin. This means that ...	➡	the original position wasn't zero. The object started somewhere other than "home base".
The slope of this graph is the ...	➡	velocity of the object.

2. Textbook question 1.2 b.:

   Object A is not moving. It is also not at the reference point.

   Object B starts at the reference point and moves away at a constant speed.

   Object C does not start from the reference point and moves away at a constant speed.

   Object D starts at the reference point and moves away at a constant speed. Note that Object D is moving slower than Object B.

   Textbook question 1.3:

   Often a sketch of a graph will do. The slope of the line at each point is the person's speed.
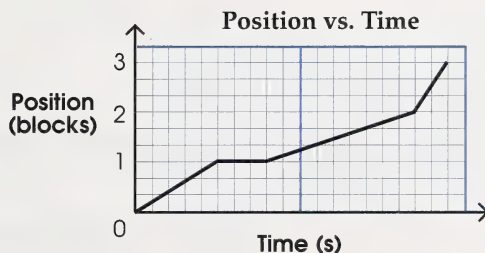
3. Answers to these problems are found on page 658 of your textbook.

4. $\vec{v}_{ave} = \dfrac{\Delta \vec{d}}{\Delta t} = \dfrac{0}{126 \text{ s}} = 0$ He ends up where he started.

   $v = \dfrac{\Delta d}{\Delta t} = \dfrac{800 \text{ m}}{126 \text{ s}} = 6.35 \text{ m/s}$ Direction doesn't matter.

5.
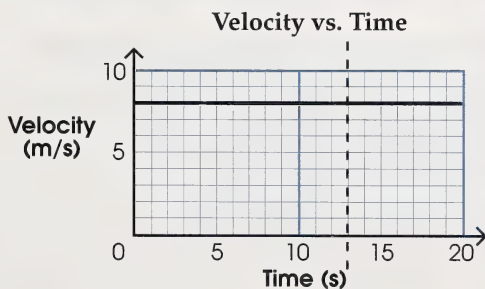
   Make a rectangle from 0 to 13 s between the line and the x-axis.

   $A = lw = (13 \text{ s})(8 \text{ m/s}) = 104 \text{ m}$

6. Answers to this problem are found on page 659 of your textbook.

7. Answers to this problem are found on page 659 of your textbook.

Section 2: Activity 3

1. a. $\vec{v}_{ave} = \dfrac{\Delta \vec{d}}{\Delta t}$

   $\vec{d} = \vec{v}_{ave}\, \Delta t$

   b. $\vec{v}_{ave} = \dfrac{\Delta \vec{d}}{\Delta t}$

   $\dfrac{1}{\vec{v}_{ave}} = \dfrac{\Delta t}{\Delta \vec{d}}$

   $\Delta t = \dfrac{\Delta \vec{d}}{\vec{v}_{ave}}$

2. $\vec{v} = ?$

   $\vec{d} = +1.00\text{ m}$

   $t = 4.05\text{ s}$

   $\vec{v} = \dfrac{\vec{d}}{t} = \dfrac{+1.00\text{ m}}{4.05\text{ s}}$

   $= 0.247\text{ m/s}$

   Its velocity is 0.247 m/s.

3. $\vec{v} = +342\text{ m/s}$

   $\vec{d} = ?$

   $t = 11.0\text{ s}$

   $\vec{d} = \vec{v}t$

   $= (+342\text{ m/s})(11.0\text{ s})$

   $= 3762\text{ m}$

   It goes 3.76×10^{3} m (or 3.76 km) in this time.

4. a. The answer to this problem is found on page 657 of your textbook.

   b. The answer to this problem is found on page 657 of your textbook.

   c. The answer to this problem is found on page 658 of your textbook.

5. a. Textbook question 5:

you: $t = \dfrac{\vec{d}}{\vec{v}} = \dfrac{+50 \text{ km}}{+90 \text{ km/h}} = 0.5555 \text{ h}$

friend: $t = \dfrac{\vec{d}}{\vec{v}} = \dfrac{+50 \text{ km}}{+95 \text{ km/h}} = 0.5263 \text{ h}$

0.5555 h − 0.5263 h = 0.0293 h = 1.8 min

Your friend will wait 1.8 min.

b. Textbook question 10:

$55 \text{ km/h} + \dfrac{3.6 \text{ km/h}}{\text{m/s}} = 15.28 \text{ m/s}$

$\vec{d} = \vec{v}t$

$\quad = +15.28 \text{ m/s}\left(0.75 \text{ s}\right)$

$\quad = +11 \text{ m}$

Ann will have moved 11 m.

c. Textbook question 12. a.:

2 h at 40 km/h $\quad \vec{d} = \vec{v}t = \left(+40 \text{ km/h}\right)\left(2 \text{ h}\right) = 80 \text{ km}$

2 h at 60 km/h $\quad \vec{d} = \vec{v}t = \left(+60 \text{ km/h}\right)\left(2 \text{ h}\right) = 120 \text{ km}$

$\vec{v}_{average} = \dfrac{\Delta \vec{d}}{\Delta t} = \dfrac{80 \text{ km} + 120 \text{ km}}{2 \text{ h} + 2 \text{ h}} = \dfrac{+200 \text{ km}}{4 \text{ h}} = 50 \text{ km/h}$

Textbook question 12. b.:

100 km at 40 km/h $\quad t = \dfrac{\vec{d}}{\vec{v}} = \dfrac{+100 \text{ km}}{+40 \text{ km/h}} = 2.5 \text{ h}$

100 km at 60 km/h $\quad t = \dfrac{\vec{d}}{\vec{v}} = \dfrac{+100 \text{ km}}{+60 \text{ km/h}} = 1.67 \text{ h}$

$\vec{v}_{average} = \dfrac{\Delta \vec{d}}{\Delta t} = \dfrac{100 \text{ km} + 100 \text{ km}}{2.5 \text{ h} + 1.67 \text{ h}} = \dfrac{+200 \text{ km}}{4.17 \text{ h}} = 48 \text{ km/h}$

No, the answers are not the same. The time that you travel at some speed is a determining factor.

Section 2: Follow-up Activities

Extra Help

1. **Term**

   position ___d___

   velocity ___c___

   vector ___f___

   displacement ___h___

   scalar ___g___

   speed ___b___

   reference point ___a___

   distance ___e___

2. There are 10 time intervals of $\frac{1}{10}$ s each, so the total time is 1.00 s. By measuring you find that the displacement is +11.0 cm.

   $$\vec{v}_{ave} = \frac{\Delta \vec{d}}{\Delta t} = \frac{+11.0 \text{ cm}}{1.00 \text{ s}} = 11.0 \text{ cm/s}$$

3. Textbook question 9. a.:

   The object travelled 10 m.

   Textbook question 9. b.:

   The object travelled 30 m.

   Textbook question 9. c.:

   The object travelled 0 m.

   Textbook question 9. d.:

   The object travelled 40 m (– 40 m displacement).

   Textbook question 9. e.:

   The object travelled 80 m (0 m displacement).

Textbook question 10. a.:

$$\frac{\text{rise}}{\text{run}} = \frac{+10 \text{ m}}{5 \text{ s}} = 2 \text{ m/s}$$

Textbook question 10 .b.:

$$\frac{\text{rise}}{\text{run}} = \frac{(40-10) \text{ m}}{(10-5) \text{ s}} = \frac{+30 \text{ m}}{5 \text{ s}} = 6 \text{ m/s}$$

Textbook question 10. c.:

The line is horizontal, so the rise is zero and the slope is zero.

Textbook question 10. d.:

$$\frac{\text{rise}}{\text{run}} = \frac{-40 \text{ m}}{5 \text{ s}} = -8 \text{ m/s} \quad \text{(A falling line has a negative slope.)}$$

4.
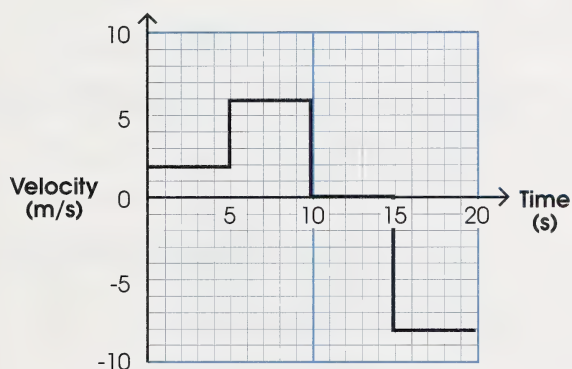
5. Step 1: $\vec{d} = ?$

   $\vec{v} = 87 \text{ km/h}$

   $t = 4.5 \text{ h}$

   Step 2: $\vec{v} = \dfrac{\vec{d}}{t}$

   $\vec{d} = \vec{v}t$

   Step 3: $\vec{d} = (+87 \text{ km/h})(4.5 \text{ h})$

Step 4: $\vec{d} = 391.5$ (Round to 390 km.)

Step 5: It went 390 km (or 3.9×10^2 km).

6. Step 1: $\Delta\vec{d} = +4.85$ km

The units do not
match, so you have
to convert them.

$\vec{v}_{ave} = ?$

$\Delta t = 12.0$ min

$\vec{d} = +4850$ m

$\vec{v}_{ave} = ?$

$t = (12)(60) = 720$ s

Step 2: $\vec{v}_{ave} = \dfrac{\Delta\vec{d}}{\Delta t}$

Step 3: $\vec{v}_{ave} = \dfrac{+4850 \text{ m}}{720 \text{ s}}$

Step 4: $\vec{v}_{ave} = 6.74$ m/s

Step 5: It is going at 6.74 m/s.

Note: You could have changed 12.0 min to 0.20 h and calculated the answer in km/h. This answer is 24.3 km/h.

7. $\vec{d} = +4.86$ m

$\vec{v} = +1.10$ cm/s $= 0.0110$ m/s

$t = ?$

$t = \dfrac{\vec{d}}{\vec{v}} = \dfrac{+4.86 \text{ m}}{+0.0110 \text{ m/s}} = 442$ s

It takes 442 s or 7.36 minutes.

8. Textbook question 3:

$\vec{d} = +100$ m

$t = 0.30$ s

$\vec{v} = ?$

$\vec{v} = \dfrac{\vec{d}}{t} = \dfrac{+100 \text{ m}}{0.30 \text{ s}} = 333$ m/s (Round to 330 m/s.)

The speed of sound is 330 m/s (or 3.3×10^3 m/s).

Textbook question 5. a.:

$\vec{v} = +720.0 \text{ m/s}$

$\vec{d} = +324 \text{ m}$ $\qquad t = \dfrac{\vec{d}}{\vec{v}} = \dfrac{+324 \text{ m}}{+720.0 \text{ m/s}} = 0.450 \text{ s}$

$t = ?$

It takes 0.450 s to hit it.

Textbook question 5. b.:

$$(+720.0 \text{ m/s})\left(\dfrac{3.6 \text{ km/h}}{\text{m/s}} \right) = 2590 \text{ km/h}$$

9. Textbook question 2:

For the first calculation (average speed), direction does not matter.

$d = 10 \text{ km}$ $\qquad\qquad\qquad v_{ave} = \dfrac{\Delta d}{\Delta t} = \dfrac{10 \text{ km}}{\dfrac{2}{3} \text{ h}}$

$t = 40 \text{ min or } \dfrac{2}{3} \text{ h}$

$\qquad\qquad\qquad\qquad\qquad v_{ave} = 15 \text{ km/h}$

For the second calculation (average velocity), direction does matter. Since she ended up where she started, $\vec{d}$ is zero. Her average velocity is zero also.

Textbook question 7:

First calculate the displacement in the first half of the trip.

$\Delta \vec{d} = \vec{v}_{ave} \Delta t$

$\qquad = (+80 \text{ km/h})(3 \text{ h})$

$\qquad = 240 \text{ km}$

After the first part of the trip, there is another 240 km to go at the slower speed. This takes 5 h. The following calculation shows your average velocity for the whole trip.

$\vec{v}_{ave} = \dfrac{\Delta \vec{d}}{\Delta t}$

$\qquad = \dfrac{240 \text{ km} + 240 \text{ km}}{3 \text{ h} + 5 \text{ h}}$

$\qquad = \dfrac{+480 \text{ km}}{8 \text{ h}}$

$\qquad = 60 \text{ km/h}$

Enrichment

1. The main idea is that the big bang occurred about 16 billion years ago. If scientists can make a telescope powerful enough to see objects 16 billion light years away, they may be able to see the universe as it was during the big bang.

2. a. Since the areas under the curves are equal to the displacements, keeping a chart of the areas should answer this question. (There are other ways to solve it, too.)

Time (s)	Position of Car A (m)	Position of Car B (m)	Separation of Cars $\left(\bar{d}_A - \bar{d}_B \right)$ (m)
0	0	0	0
5	+ 65	– 10	75
8	+ 104	– 31	135
16	+ 136	– 87	223
20	+ 104	– 108	212
24	+ 72	– 108	180
30	+ 24	– 78	102

The maximum separation is 223 m. At this point Car A changes direction and heads towards Car B.

b. Putting the information in a chart will help you solve this problem.

	d	v	t
Norm		65 km/h	
Lisa		95 km/h	

Now find an algebraic value for time or distance.

If you let t equal the time taken by Lisa, $t + 1\frac{1}{2}$ is Norm's time. You can calculate d using $d = vt$.

	d	v	t
Norm	$65\left(t+1\dfrac{1}{2}\right)$	65 km/h	$t+1\dfrac{1}{2}$
Lisa	$95t$	95 km/h	t

When Lisa catches up, their distances travelled are equal, so you can use the following equation.

$$65\left(t+1\tfrac{1}{2}\right)=95t$$
$$65t+97.5=95t$$
$$97.5=30t$$
$$t=3.25\text{ h}=3\text{ h }15\text{ min}$$

$$d=vt\quad(\text{for Lisa})$$
$$=(95\text{ km/h})(3.25\text{ h})$$
$$=310\text{ km}$$

Lisa catches up to Norm 310 km from town at 12:45 p.m.

Another way to solve this problem is to calculate Norm's headstart.

$$d=vt$$
$$=(65\text{ km/h})(1.5\text{ h})$$
$$=97.5\text{ km}$$

Their relative speed is 95 km/h − 65 km/h = 30 km/h (This is how fast Lisa is catching up to Norm.). You can use the relative speed to calculate how long it takes Lisa to catch up to Norm.

$$t=\frac{d}{v}=\frac{97.5\text{ km}}{30\text{ km/h}}=3.25\text{ h}$$

c. Textbook question 4:

Each turn of the wheel moves the car the distance of one circumference forward.

$$C=2\pi r$$
$$=2\pi(0.62\text{ m})$$
$$=3.8956\text{ m}$$

If the tires rotate 5 times in 1 s, you can calculate how far the car moves in 1 s.

$(3.8956 \text{ m/rev}) (5 \text{ rev/s}) = 19.48 \text{ m/s} = 19 \text{ m/s}$

The vehicle is moving at 19 m/s.

Section 3: Activity 1

1. The answer to this problem is found on page 659 of your textbook.

2. The answers to these problems are found on pages 659 and 660 of your textbook.

3. The acceleration is lower with an air bag since the time interval is longer. The importance of this will become clear in Module 2.

4. Your velocity would change by the same amount each second (or any time interval) of your trip.

5. Textbook question 9:

   The solution to this problem is found on page 660 of your textbook.

   Textbook question 10:

   Your textbook converts the acceleration unit. If you converted the speed unit, the solution is as follows:

   $$30 \text{ km/h} + \frac{3.6 \text{ km/h}}{\text{m/s}} = 8.33 \text{ m/s}$$

   $$v_f = v_i + at$$
   $$= 8.33 \text{ m/s} + \left(3.5 \text{ m/s}^2\right)\left(6.8 \text{ s}\right)$$
   $$= 8.33 \text{ m/s} + 23.8 \text{ m/s}$$
   $$= \left(32.1 \text{ m/s}\right)\left(3.6 \frac{\text{km/h}}{\text{m/s}}\right)$$
   $$= 116 \text{ km/h}$$
   $$= 1.2 \times 10^2 \text{ km/h}$$

   The bus has a velocity of 116 km/h (or 1.2×10^2 km/h).

Textbook question 11:

After you solve for t, you end up dividing 28 m/s by 5.5 m/s². Here is how the units work:

$$\frac{m}{s} \div \frac{m}{s^2} = \frac{\cancel{m}}{\cancel{s}} \times \frac{\overset{1}{\cancel{s^2}}}{\cancel{m}}$$

$$= \frac{s}{1}$$

$$= s$$

Refer to the rest of the solution on page 660 of your textbook.

Section 3: Activity 2

1. Textbook question 6:

    The answer to this question appears on page 660 of your textbook.

    Textbook question 7:

    The answer to this question appears on page 660 of your textbook. Finding the slope for each time interval will give you the value for average acceleration in each interval.

2. $\text{slope} = \dfrac{\text{rise}}{\text{run}} = \dfrac{60 \text{ m/s} - 0 \text{ m/s}}{30 \text{ s} - 0 \text{ s}} = \dfrac{60 \text{ m/s}}{30 \text{ s}} = 2.0 \text{ m/s}^2$

    (You may have used different points to find the slope.)

    Yes, the slope does equal the acceleration.

3. The graph is a straight line. Its slope never changes.

4. Textbook question 2. a.:

    It moves at a constant 10 m/s.

    Textbook question 2. b.:

    It slows down from 10 m/s to a stop in 2 s.

Textbook question 2. c.:

$$a_{average} = 0 \quad \text{(no change of velocity)}$$

Textbook question 2. d.:

$$a_{average} = \frac{v_f - v_i}{\Delta t} = \frac{0 - 10 \text{ m/s}}{6 \text{ s} - 4 \text{ s}} = \frac{-10 \text{ m/s}}{2 \text{ s}} = -5 \text{ m/s}^2$$

The negative value means that the car is slowing down.

5. a.
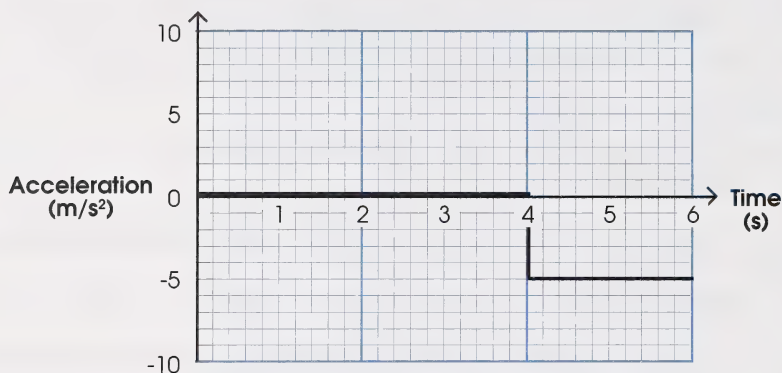
b. The area under the curve is calculated using the area of a rectangle for $t = 4$ s to $t = 6$ s. Note that for $t = 0$ s to $t = 4$ s, the area is zero.

$$A = lw$$
$$= \left(-5 \text{ m/s}^2\right)\left(2 \text{ s}\right)$$
$$= -10 \text{ m/s}$$

This area represents the change in velocity from $t = 4$ s to $t = 6$ s.

6.

Time		Position from Start (cm)	Displacement Between Dots (cm)
Dot	(s)		
First	0	0	
			1.0
Second	0.10	1.0	
			1.5
Third	0.20	2.5	
			2.0
Fourth	0.30	4.5	
			2.5
Fifth	0.40	7.0	
			3.0
Sixth	0.50	10.0	
			3.5
Seventh	0.60	13.5	
			3.9
Eighth	0.70	17.4	
			4.5
Ninth	0.80	21.9	

7. The dots are getting further apart because the object is speeding up. It can go further in the same amount of time.

8.

Time		$\bar{v}_{ave}$ Between Dots (cm/s)	Time when $\bar{v}_{ave}$ Occurred (s)
Dot	(s)		
First	0		
		10	0.05
Second	0.10		
		15	0.15
Third	0.20		
		20	0.25
Fourth	0.30		
		25	0.35
Fifth	0.40		
		30	0.45
Sixth	0.50		
		35	0.55
Seventh	0.60		
		39	0.65
Eighth	0.70		
		45	0.75
Ninth	0.80		

9. The times are shown on the chart provided for question 8.

10.

Time		$\bar{v}_{ave}$ Between Dots (cm/s)	$\Delta\bar{v}$ (cm/s)
Dot	(s)		
First	0		
		10	5
Second	0.10		
		15	5
Third	0.20		
		20	5
Fourth	0.30		
		25	5
Fifth	0.40		
		30	5
Sixth	0.50		
		35	4
Seventh	0.60		
		39	6
Eighth	0.70		
		45	
Ninth	0.80		

11.

Time		$\Delta\bar{v}$ (cm/s)	Acceleration (cm/s^2)
Dot	(s)		
First	0	–	–
Second	0.10	5	50
Third	0.20	5	50
Fourth	0.30	5	50
Fifth	0.40	5	50
Sixth	0.50	5	50
Seventh	0.60	4	40
Eighth	0.70	6	60
Ninth	0.80	–	–

12. If the object is speeding up, it will cover more and more distance each second.

13. The average velocity during a time interval is the instantaneous velocity only at the centre of the time interval.

14. The y-intercept represents the initial velocity. The object was already moving when the interval timer began.

15. The slope is calculated using the end points.

$$\text{slope} = \frac{\text{rise}}{\text{run}}$$

$$= \frac{47 \text{ cm/s} - 8 \text{ m/s}}{0.80 \text{ s} - 0 \text{ s}}$$

$$= \frac{39 \text{ cm/s}}{0.80 \text{ s}}$$

$$= 49 \text{ cm/s}^2$$

This value is very close to the calculated value for acceleration.

16. a.

Time (s)	Position (cm)	Displacement from Previous Dot (cm)
0	0	–
0.30	0.5	0.5
0.60	1.5	1.0
0.90	3.0	1.5
1.20	5.0	2.0
1.50	7.4	2.4
1.80	10.4	3.0
2.10	14.0	3.6

b.

Time (s)	Average Velocity in an Interval (cm/s)	$\Delta\bar{v}$ (cm/s)	Acceler-ation (cm/s²)
0	–	–	–
0.30	1.67	–	–
0.60	3.33	1.66	5.53
0.90	5.00	1.67	5.57
1.20	6.67	1.67	5.57
1.50	8.00	1.33	4.43
1.80	10.0	2.00	6.67
2.10	12.0	2.00	6.67

c. To calculate the value for average acceleration, you would add up all the acceleration values and divide the sum by 6. Your value should be 5.7 cm/s². Extra significant digits were kept on the data chart to reduce the errors from rounded off calculations. However, the values should be regarded as precise to two digits only.

d.

Position vs. Time

Position (cm)

Time (s)

e. **Average Velocity vs. Time**

Average Velocity (cm/s)

$10 \text{ cm/s} - 3.5 \text{ cm/s} = 6.5 \text{ cm/s}$

$1.65 \text{ s} - 0.5 \text{ s} = 1.15 \text{ s}$

Time (s)
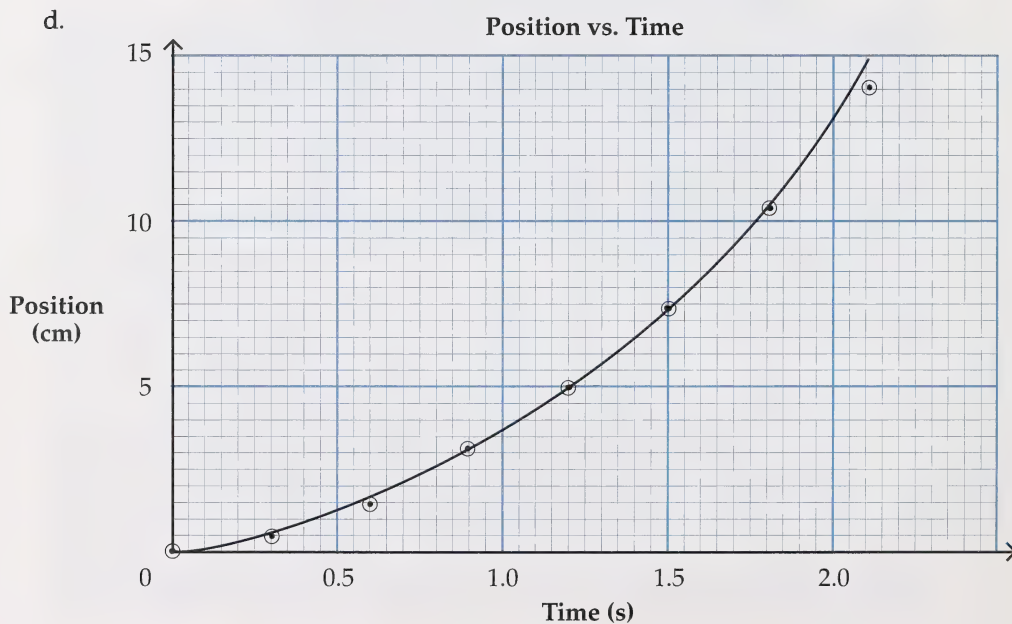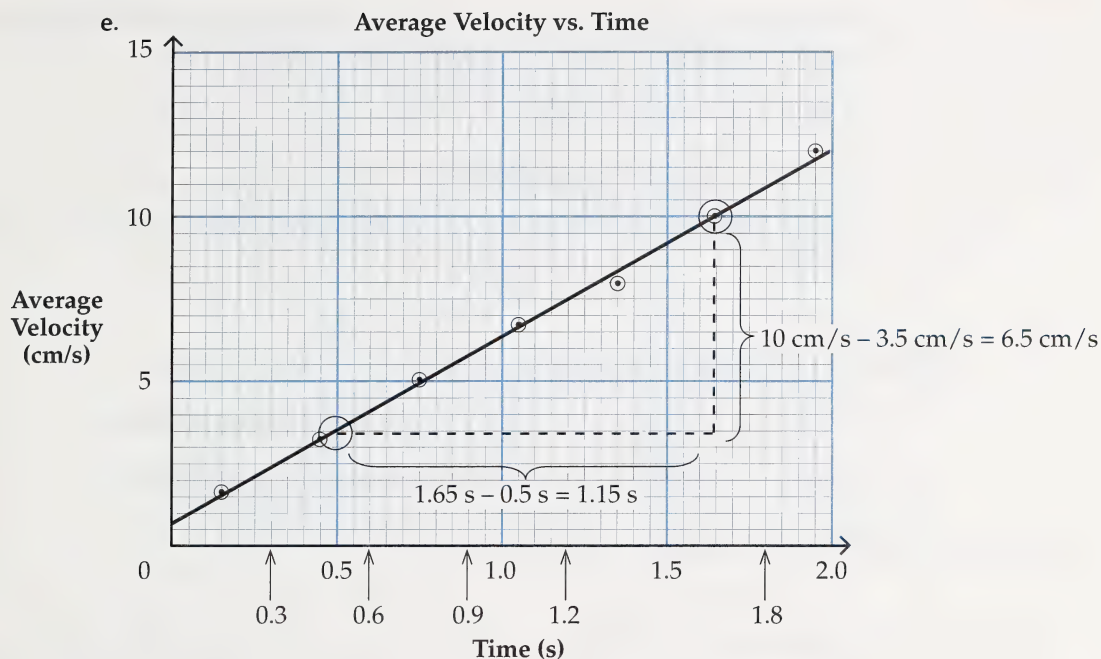
Note that each velocity has been plotted at a time that occurs midway in each interval.

f. $\text{slope} = \dfrac{\text{rise}}{\text{run}} = \dfrac{6.5 \text{ cm/s}}{1.15 \text{ s}} = 5.65 \text{ cm/s}^2 = 5.7 \text{ cm/s}^2$ (to two significant digits)

g.   Using the y-intercept, the initial velocity is about 0.7 cm/s. Using the slope, the acceleration is 5.7 cm/s^2.

17.   When choosing an interval timer, consider things that produce a regular beat. The following are given as ideas only. Your answers may differ from these.

- water dropper

- baby bottle

- leaking tap

- pendulum

- scratched record (The needle will make a clicking sound each time it crosses the scratch.)

18. The setup that you use will be individual to you. Your creativity is your only limit. A list of possible solutions follows. Your answer may vary from these.

   - strobe light and photograph

   - water dripping from a pail swinging on a rope

   - your finger touching the surface beside the moving object in time to your interval timer

Section 3: Activity 3

1. The answers to these problems are found on page 660 of your textbook.

2. The answers to these problems are found on page 660 of your textbook.

3. Textbook question 21:

$v_i = 21\,\text{m/s}$

$a = 3.0\,\text{m/s}^2$

$d = 535\,\text{m}$

$v_f = ?$

$$* \; v_f{}^2 = v_i{}^2 + 2ad$$
$$= (21\,\text{m/s})^2 + 2(3.0\,\text{m/s}^2)(535\,\text{m})$$
$$= 441\,\text{m}^2/\text{s}^2 + 3210\,\text{m}^2/\text{s}^2$$
$$v_f{}^2 = 3651\,\text{m}^2/\text{s}^2$$
$$v_f = \sqrt{3651\,\text{m}^2/\text{s}^2}$$
$$v_f = 60\,\text{m/s}$$

*Be sure to use the scalar version of this equation.

Textbook question 22:

$d = 484\,\text{m}$

$v_f = 0$

$a = -8.0\,\text{m/s}^2$

$v_i = ?$

$$* \; v_f{}^2 = v_i{}^2 + 2ad$$
$$v_i{}^2 = v_f{}^2 - 2ad$$
$$= 0 - 2(-8.0\,\text{m/s}^2)(484\,\text{m})$$
$$v_i{}^2 = 7744\,\text{m}^2/\text{s}^2$$
$$v_i = \sqrt{7744\,\text{m}^2/\text{s}^2}$$
$$= 88\,\text{m/s}$$

*Be sure to use the scalar version of this equation.

4. Textbook question 10:

$$\vec{d} = ?$$
$$\vec{v}_i = +66 \text{ m/s}$$
$$\vec{v}_f = +88 \text{ m/s}$$
$$t = 12 \text{ s}$$

$$\vec{d} = \left(\frac{\vec{v}_i + \vec{v}_f}{2}\right)t$$

$$= \left[\frac{(+66 \text{ m/s}) + (+88 \text{ m/s})}{2}\right]12 \text{ s}$$

$$= (+77 \text{ m/s})(12 \text{ s})$$

$$= 924 \text{ m}$$

It goes 920 m in the original direction (rounded to two significant digits).

Textbook question 12. a.:

$$\vec{v}_i = +12 \text{ m/s}$$
$$\vec{a} = -1.6 \text{ m/s}^2$$
$$t = 6.0 \text{ s}$$
$$\vec{d} = ?$$

$$\vec{d} = \vec{v}_i t + \frac{1}{2}\vec{a}t^2$$

$$= (+12 \text{ m/s})(6.0 \text{ s}) + \frac{1}{2}(-1.6 \text{ m/s}^2)(6.0 \text{ s})^2$$

$$= +72 \text{ m} - 28.8 \text{ m}$$

$$= +43.2 \text{ m}$$

It goes 43 m in the original direction.

Textbook question 12. b.:

$$t = 9.0 \text{ s}$$

$$\vec{d} = \vec{v}_i t + \frac{1}{2}\vec{a}t^2$$

$$= (+12 \text{ m/s})(9.0 \text{ s}) + \frac{1}{2}(-1.6 \text{ m/s}^2)(9.0 \text{ s})^2$$

$$= +108 \text{ m} - 64.8 \text{ m}$$

$$= +43.2 \text{ m}$$
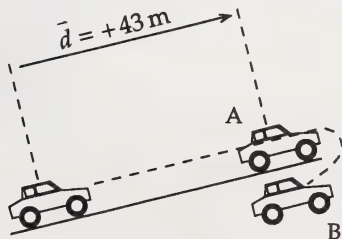
It goes 43 m as well!

It stops and comes back down to the same position as in 12. a.

Textbook question 16:

$d = 5.0 \times 10^2$ m

$a = 5.0$ m/s^2

$v_f = ?$

$v_i = 0$

$$v_f{}^2 = v_i{}^2 + 2ad$$
$$= 0^2 + 2(5.0 \text{ m/s}^2)(5.0 \times 10^2 \text{ m})$$
$$= 5.0 \times 10^3 \text{ m/s}$$

It's going at 5.0×10^3 m/s.

Textbook question 20. a.:

$v_i = 0$

$v_f = 3.5$ km/s $= 3500$ m/s

$a = ?$

$d = 2.0$ cm $= 0.020$ m

$$v_f{}^2 = v_i{}^2 + 2ad$$
$$a = \frac{v_f{}^2 - v_i{}^2}{2d}$$
$$= \frac{(3500 \text{ m/s})^2 - 0}{2(0.020 \text{ m})} = 3.1 \times 10^8 \text{ m/s}^2$$

Acceleration is 3.1×10^8 m/s^2.

Textbook question 20. b.:

There are many possible methods to solve this problem.

$$\vec{d} = \left(\frac{\vec{v}_i + \vec{v}_f}{2}\right)t$$

$$t = \left(\frac{2\vec{d}}{\vec{v}_i + \vec{v}_f}\right)$$

$$= \frac{2(0.020 \text{ m})}{0 + 3500 \text{ m/s}}$$

$$= 1.1 \times 10^{-5} \text{ s}$$

It takes 1.1×10^{-5} s or 11 μs.

5. In the textbook $\vec{g}$ is given a value of -9.80 m/s^2.

6. The acceleration due to gravity is a vector, and therefore it must have direction. For the sake of consistency, the textbook uses "up" as the positive direction and "down" as the negative direction. Since things always accelerate down (towards the centre of the earth) when they fall freely, the direction for $\vec{g}$ should be negative.

7. Before $\vec{a}$ can be replaced with $\vec{g}$, it must be assumed that there is no significant amount of air resistance.

8. The answers to these problems can be found on page 661 of your textbook.

9. If your distance is about 1.0 m, you should get in the low 20s for the number of drops in 10 s.

   The following is sample data only.

	Distance for Each Drop (m)	Number of Drops in 10 s	Time Between Drops (s)
Trial 1	0.982	24	0.42
Trial 2	0.475	32	0.31

10. The following results were calculated using the sample data provided in question 9.

	$g = \dfrac{2d}{t^2}$ (in m/s²)
Trial 1	11
Trial 2	9.9
Average Value of g	10

Trial 1: $\quad g = \dfrac{2d}{t^2}$

$\qquad = \dfrac{2(0.982 \text{ m})}{(0.42 \text{ s})^2}$

$\qquad = 11.1 \text{ m/s}^2$

Trial 2: $\quad g = \dfrac{2d}{t^2}$

$\qquad = \dfrac{2(0.475 \text{ m})}{(0.31 \text{ s})^2}$

$\qquad = 9.89 \text{ m/s}^2$

11. No. Human reaction time is at best about 0.18 s. This is over 30% of the time interval in this instance.

12. It's pretty good if you're really careful getting the timing correct. The drops must stay consistent throughout.

13. You won't get a lot of dots unless the timer can give you $\frac{1}{100}$-s intervals. Here are some things to remember when recording observations and calculating.

- Measure distances carefully.

- Speed is the distance divided by some period of time.

- Subtract adjacent average speeds to get the changes in speed.

- All of the changes in speed occur in the same length of time intervals, so

$$a = \frac{\Delta v}{t}.$$

- For sample data and analysis refer to Activity 2 in Section 3.

14. Your value should be very accurate if the timer is good and the paper tape runs through the timer smoothly. Often a value below the expected one is found because of friction caused by the tape moving through the timer.

Note: The more swings you can time, the better. Good choices for the string include thread, dental floss, and fishing line. Good choices for a mass include marbles, bowling balls, and nuts from a bolt. If the pendulum starts circling instead of going back and forth, watch it from the side and keep timing.

15. The following measurements are in the right range for pendulums of the given lengths. Your answers may vary.

	Length (m)	Time for 30 swings (s)
First Pendulum	0.50	42
Second Pendulum	1.00	60

16. a. $\dfrac{42\text{ s}}{30\text{ swings}} = 1.4$ s per swing $\qquad\qquad$ $\dfrac{60\text{ s}}{30\text{ swings}} = 2.0$ s per swing

b. $g = \dfrac{4\pi^2 l}{T^2} = \dfrac{4\pi^2\left(0.50\text{ m}\right)}{\left(1.4\text{ s}\right)^2}$ $\qquad\qquad$ $g = \dfrac{4\pi^2 l}{T^2} = \dfrac{4\pi^2\left(1.00\text{ m}\right)}{\left(2.0\text{ s}\right)^2}$

$g = 10.1\text{ m/s}^2$ $\qquad\qquad\qquad\qquad$ $g = 9.9\text{ m/s}^2$

c. Average value $= \dfrac{10.1\text{ m/s}^2 + 9.9\text{ m/s}^2}{2} = 10\text{ m/s}^2$

17. You can be extremely close with this experiment! The way to get a really precise value for g is to use a very long pendulum and time for a long time. A wildly swinging pendulum won't get you a very close result.

18. If 3415 frames last 1 s, 1 frame lasts $1/3415$ s or 2.928×10^{-4} s.

19. The bowling ball took 152 frames to travel 20 cm. If you assume that each frame equals 2.928×10^{-4} s, you would calculate the time as shown.

$$t = 152\left(2.928 \times 10^{-4}\text{ s}\right)$$
$$= 0.044\ 51\text{ s}$$

20. The 1-m mark is the midpoint of the 20-cm region. Since this is uniformly accelerated motion, the instantaneous velocity at the midpoint equals the average velocity over the time interval.

$$\begin{pmatrix}\text{velocity of the}\\ \text{ball after}\\ \text{falling 1 m}\end{pmatrix} = v_f = v_{ave} = \dfrac{\Delta d}{\Delta t}$$
$$= \dfrac{0.20\text{ m}}{0.044\ 51\text{ s}}$$
$$= 4.49\text{ m/s}$$

(Since this value will be used again, it is not rounded off yet.)

21. $v_i = 0$

   $d = -1.0$ m

   $v_f = -4.49$ m/s

   $a = ?$

$$v_f{}^2 = v_i{}^2 + 2gd$$

$$v_f{}^2 = 2gd$$

$$g = \frac{v_f{}^2}{2d}$$

$$g = \frac{(4.49 \text{ m/s})^2}{2(1.0 \text{ m})}$$

$$g = 10 \text{ m/s}^2$$

The value for g would be 10 m/s^2.

22.

Number of Frames for the Ball to Fall Through 20 cm (frames)	Time for the Ball to Fall 20 cm (s)	Speed of the Ball at the Metre Mark (m/s)	Value for g (m/s²)
$\dfrac{27\,888 - 27\,736}{152}$	$152\left(2.928 \times 10^{-4}\ \text{s}\right)$ $= 0.044\,51\ \text{s}$	$v_f = v_{ave} = \dfrac{\Delta d}{\Delta t}$ $= \dfrac{0.20\ \text{m}}{0.044\,51\ \text{s}}$ $= 4.49\ \text{m/s}$	$a = \dfrac{v_f^{\,2}}{2d}$ $= \dfrac{\left(4.49\ \text{m/s}\right)^2}{2\left(1.0\ \text{m}\right)}$ $= 10\ \text{m/s}^2$
$\dfrac{28\,039 - 27\,938}{101}$	$101\left(2.928 \times 10^{-4}\ \text{s}\right)$ $= 0.029\,58\ \text{s}$	$v_f = v_{ave} = \dfrac{\Delta d}{\Delta t}$ $= \dfrac{0.20\ \text{m}}{0.029\,58\ \text{s}}$ $= 6.76\ \text{m/s}$	$a = \dfrac{v_f^{\,2}}{2d}$ $= \dfrac{\left(6.76\ \text{m/s}\right)^2}{2\left(2.0\ \text{m}\right)}$ $= 11\ \text{m/s}^2$
$\dfrac{28\,185 - 28\,096}{89}$	$89\left(2.928 \times 10^{-4}\ \text{s}\right)$ $= 0.026\,06\ \text{s}$	$v_f = v_{ave} = \dfrac{\Delta d}{\Delta t}$ $= \dfrac{0.20\ \text{m}}{0.026\,06\ \text{s}}$ $= 7.67\ \text{m/s}$	$a = \dfrac{\left(v_f\right)^2}{2d}$ $= \dfrac{\left(7.67\ \text{m/s}\right)^2}{2\left(3.0\ \text{m}\right)}$ $= 9.8\ \text{m/s}^2$
$\dfrac{28\,316 - 28\,236}{80}$	$80\left(2.928 \times 10^{-4}\ \text{s}\right)$ $= 0.023\,43\ \text{s}$	$v_f = v_{ave} = \dfrac{\Delta d}{\Delta t}$ $= \dfrac{0.20\ \text{m}}{0.023\,43\ \text{s}}$ $= 8.54\ \text{m/s}$	$a = \dfrac{\left(v_f\right)^2}{2d}$ $= \dfrac{\left(8.54\ \text{m/s}\right)^2}{2\left(4.0\ \text{m}\right)}$ $= 9.1\ \text{m/s}^2$

What is the average value for g?

$$= \frac{\left(10 + 11 + 9.8 + 9.1\right)\ \text{m/s}^2}{4}$$

$$= 10\ \text{m/s}^2$$

23. Note that the important skill here is to determine the exact frame numbers when the centre of the ball crosses the 20-cm boundary lines. Since the ball is so large, this is difficult to do. An improvement would be to have a mark on the ball to determine the exact instant the ball crosses the 20-cm boundary.

24. Answers will vary. If you came within 5%, you did well. The pendulum will often come within 1%.

25. % error $= \left| \dfrac{\left(10.61 \, \text{m/s}^2\right) - \left(9.81 \, \text{m/s}^2\right)}{9.81 \, \text{m/s}^2} \right| \times 100\% = 8.2\%$

26. Textbook question 1:

$\vec{v}_i = +40 \, \text{m/s}$

$\vec{v}_f = 0$

$\vec{a} = ?$

$t = 0.012 \, \text{s}$

$\vec{a} = \dfrac{\vec{v}_f - \vec{v}_i}{t}$

$= \dfrac{0 - 40 \, \text{m/s}}{0.012 \, \text{s}}$

$= -3.3 \times 10^3 \, \text{m/s}^2$

The acceleration is $-3.3 \times 10^3 \, \text{m/s}^2$. The negative sign means that the ball was slowing down (decelerating).

Textbook question 4:

$\vec{a} = 12.5 \, \text{m/s}^2$

$\vec{v}_i = 0$

$\vec{v}_f = 100 \, \text{m/s}$

$t = ?$

$\vec{v}_f = \vec{v}_i + \vec{a}t$

$t = \dfrac{\vec{v}_f - \vec{v}_i}{\vec{a}}$

$= \dfrac{+100 \, \text{m/s} - 0}{+12.5 \, \text{m/s}^2}$

$= 8.00 \, \text{s}$

It takes 8.00 s.

Textbook question 8. a.:

$$\vec{a} = +6.8 \times 10^4 \text{ m/s}^2$$
$$\vec{v}_i = 0$$
$$\vec{d} = +0.80 \text{ m}$$
$$t = ?$$

$$\vec{d} = \vec{v}_i t + \frac{1}{2}\vec{a}t^2$$

$\vec{v}_i$ is zero so

$$\vec{d} = \frac{1}{2}\vec{a}t^2$$

$$t = \sqrt{\frac{2\vec{d}}{\vec{a}}}$$

$$= \sqrt{\frac{2(0.80 \text{ m})}{6.8 \times 10^4 \text{ m/s}^2}}$$

$$= 4.9 \times 10^{-3} \text{ s}$$

It takes 4.9×10^{-3} s or 4.9 ms to do this.

Textbook question 8. b.:

$$\vec{v}_f = \vec{v}_i + \vec{a}t$$

$$= 0 + \left(6.8 \times 10^4 \text{ m/s}^2\right)\left(4.8507 \times 10^{-3} \text{ s}\right)$$

$$= 3.3 \times 10^2 \text{ m/s}$$

4.8507×10^{-3} s is the unrounded version of t that you calculated in 8. a.

Textbook question 12:

$$d = +60 \text{ m}$$
$$a = -10 \text{ m/s}^2$$
$$\vec{v}_f = 0$$
$$\vec{v}_i = ?$$

$$v_f^2 = v_i^2 + 2ad$$

$$v_i^2 = v_f^2 - 2ad$$

$$v_i^2 = 0^2 - 2\left(-10 \text{ m/s}^2\right)\left(60 \text{ m}\right)$$

$$v_i^2 = +1200 \text{ m}^2/\text{s}^2$$

$$v_i = \sqrt{1200 \text{ m}^2/\text{s}^2}$$

$$= 34.6 \text{ m/s}$$

$$= 35 \text{ m/s}$$

$34.6 \text{ m/s}\left(\dfrac{3.6 \text{ km/h}}{\text{m/s}}\right) = 125 \text{ km/h}$. The car was way over the speed limit.

Textbook question 14. a.:

$$\vec{v}_i = 0$$

$$\vec{v}_f = \vec{v}_i + \vec{a}t$$

$$\vec{a} = \vec{g} = -9.80 \text{ m/s}^2$$

$$= 0 + \left(-9.80 \text{ m/s}^2\right)\left(6.0 \text{ s}\right)$$

$$t = 6.0 \text{ s}$$

$$= -58.8 \text{ m/s}$$

$$\vec{v}_f = ?$$

$$= -59 \text{ m/s}$$

Its velocity is -59 m/s or 59 m/s downward.

Textbook question 14. b.:

$$\vec{d} = \left(\frac{\vec{v}_i + \vec{v}_f}{2}\right)t$$

$$= \left(\frac{0 + \left(-58.8 \text{ m/s}\right)}{2}\right)6.0 \text{ s}$$

$$= -176.4 \text{ m}$$

$$= -1.8 \times 10^2 \text{ m}$$

The ground is at displacement of 1.8×10^{-2} m below the cliff, so the cliff is 1.8×10^2 m high.

Textbook question 16:

$$\vec{v}_i = +4.2 \text{ m/s}$$

$$\vec{d} = \vec{v}_i t + \frac{1}{2}\vec{g}t^2$$

$$\vec{a} = \vec{g} = -9.80 \text{ m/s}^2$$

$$t = 2.5 \text{ s}$$

$$= \left(4.2 \text{ m/s}\right)\left(2.5 \text{ s}\right) + \frac{1}{2}\left(-9.80 \text{ m/s}^2\right)\left(2.5 \text{ s}\right)^2$$

$$\vec{d} = ?$$

$$= 10.5 \text{ m} - 30.625$$

$$= -20 \text{ m}$$

The diver went up 10.5 m and down 30.625 m. The water is 20 m below the platform.

27. The following list of equations represents the main ideas from this module. It is important that your list not be too long, as room must be left for the equations from future modules.

- Uniform Motion: $\vec{v} = \dfrac{\vec{d}}{t}$ or $\vec{d} = \vec{v}t$

- Uniformly Accelerated Motion: $\vec{v}_{ave} = \dfrac{\Delta \vec{d}}{\Delta t}$

$$\vec{a} = \dfrac{\vec{v}_f - \vec{v}_i}{t} \text{ or } \vec{v}_f = \vec{v}_i + \vec{a}t$$

$$\vec{v}_{ave} = \dfrac{\vec{v}_f + \vec{v}_i}{2}$$

$$\vec{d} = \left(\dfrac{\vec{v}_f + \vec{v}_i}{2}\right)t$$

$$\vec{d} = \vec{v}_i t + \dfrac{1}{2}\vec{a}t^2$$

$$v_f^2 = v_i^2 + 2ad$$

Section 3: Follow-up Activities

Extra Help

1. $\Delta \vec{v} = +15 \text{ m/s} - 0 = +15 \text{ m/s}$

    $t = 6.0 \text{ s}$

    $\vec{a} = \dfrac{\Delta \vec{v}}{t} = \dfrac{+15 \text{ m/s}}{6.0 \text{ s}} = 2.5 \text{ m/s}^2$

2. $\Delta \vec{v} = 40 \text{ km/h} - 85 \text{ km/h} = -45 \text{ km/h}$

    $t = 9.0 \text{ s}$

    $\vec{a} = \dfrac{\Delta \vec{v}}{t} = \dfrac{-45 \text{ km/h}}{9.0 \text{ s}} = -5.0 \text{ km/h} \bullet \text{s}$

3. a.

	Displacement (m)
Interval 1	2.0
Interval 2	2.3
Interval 3	2.6
Interval 4	2.9

b.

	Average Velocity (m/s)
Interval 1	$\vec{v}_{ave} = \dfrac{\Delta \vec{d}}{\Delta t} = \dfrac{+2.0\ m}{0.5\ s} = 4.0\ m/s$
Interval 2	$\vec{v}_{ave} = \dfrac{+2.3\ m}{0.5\ s} = 4.6\ m/s$
Interval 3	$\vec{v}_{ave} = \dfrac{+2.6\ m}{0.5\ s} = 5.2\ m/s$
Interval 4	$\vec{v}_{ave} = \dfrac{+2.9\ m}{0.5\ s} = 5.8\ m/s$

c. First to second interval: 4.6 m/s – 4.0 m/s = 0.6 m/s

Second to third interval: 5.2 m/s – 4.6 m/s = 0.6 m/s

Third to fourth interval: 5.8 m/s – 5.2 m/s = 0.6 m/s

d.

	Acceleration (m/s²)
Interval 1 to Interval 2	$\dfrac{\Delta \bar{v}}{t} = \dfrac{+0.6 \text{ m/s}}{0.5 \text{ s}} = 1.2 \text{ m/s}^2$
Interval 2 to Interval 3	1.2
Interval 3 to Interval 4	1.2

e. It's 1.2 m/s². All values are equal.

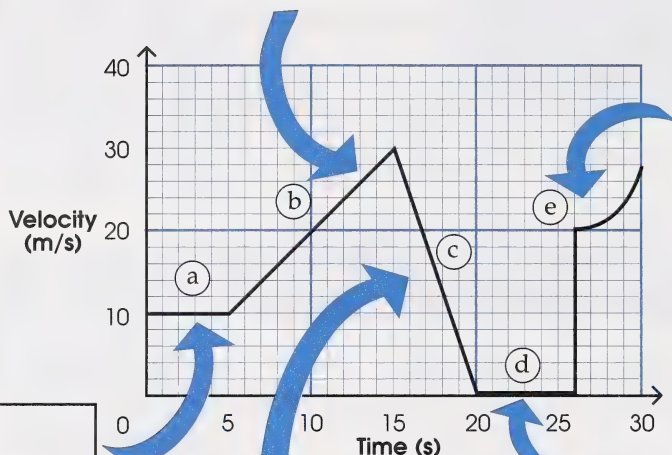4. a. The slope is equal to the acceleration.

$$\text{slope} = \frac{\text{rise}}{\text{run}} = \frac{10 \text{ m/s} - 0}{30 \text{ s} - 0} = +0.33 \text{ m/s}^2$$

b. Displacement is equal to the area of the triangle.

$$A = \frac{1}{2}ab$$
$$= \frac{1}{2}(+10 \text{ m/s})(30 \text{ s})$$
$$= 150 \text{ m}$$

5.

6. $v_i = 0$

     $v_f = 95$ m/s   The missing variable is t, so

     $d = 450$ m   use the equation that does

     $a = ?$ not have a t.

$$* v_f{}^2 = v_i{}^2 + 2ad$$

$$a = \frac{v_f{}^2 - v_i{}^2}{2d}$$

$$= \frac{(95 \text{ m/s})^2 - 0}{2(450 \text{ m})}$$

$$= 10 \text{ m/s}^2$$

Its acceleration is 10 m/s^2.

*Note that this equation was not written in vector form.

7. $\bar{v}_i = 6.2$ m/s $\bar{v}_f = \bar{v}_i + \bar{a}t$

    $\bar{v}_f = 0$

    $\bar{a} = -2.5 \text{ m/s}^2$ $t = \dfrac{\bar{v}_f - \bar{v}_i}{\bar{a}}$

    $t = ?$ $= \dfrac{0 - 6.2 \text{ m/s}}{-2.5 \text{ m/s}^2}$

                             $= 2.5$ s

It took 2.5 s to do this.

Enrichment

1. a.

Time (s)		Position (cm)	Displacement from Previous Dot (cm)
0	= 0	0	–
$\frac{1}{120}$	= 0.008 33	2.2	2.2
$\frac{2}{120}$	= 0.0167	5.2	3.0
$\frac{3}{120}$	= 0.0250	8.6	3.4
$\frac{4}{120}$	= 0.0333	12.6	4.0

b.

Time (s)	Average Velocity in Interval (cm/s)	$\Delta\bar{v}$ (cm/s)	Acceleration (cm/s^2)
0	–	–	–
0.008 33	264	–	–
0.0167	360	96	11 520
0.0250	408	48	5760
0.0333	480	72	8640

c. What is wrong is the huge difference between acceleration values. The strobe may be flashing irregularly or the ball may be held up by air currents. This does not behave like a uniform acceleration. If air resistance was zero and the scale was known, the acceleration due to gravity should be a constant value of 9.8 m/s^2 or 980 cm/s^2.

2. $\vec{v}_f = \vec{v}_i + \vec{a}t$, so $\vec{v}_i = \vec{v}_f - \vec{a}t$

$$\vec{d} = \left(\frac{\vec{v}_i + \vec{v}_f}{2}\right)t$$

$$\vec{d} = \left(\frac{\left(\vec{v}_f - \vec{a}t\right) + \vec{v}_f}{2}\right)t$$

$$\vec{d} = \left(\frac{2\vec{v}_f - \vec{a}t}{2}\right)t$$

$$= \left(\frac{2\vec{v}_f}{2} - \frac{\vec{a}t}{2}\right)t$$

$$= \vec{v}_f t - \frac{1}{2}\vec{a}t^2$$

Here it is. It isn't used very often and isn't usually derived.

3. Textbook question 25. a.:

$$\vec{v}_i = \left(+90 \text{ km/h}\right)\left(\frac{1 \text{ m/s}}{36 \text{ km/h}}\right)$$

$$= +25.0 \text{ m/s}$$

Reaction time (constant velocity)

$$\vec{d} = \vec{v}_i t$$

$$= +25.0 \text{ m/s}\left(0.75 \text{ s}\right)$$

$$= +18.75 \text{ m}$$

Braking (constant acceleration)

$$v_f^2 = v_i^2 + 2ad$$

$$d = \frac{v_f^2 - v_i^2}{2a}$$

$$= \frac{0^2 - \left(25.0 \text{ m/s}\right)^2}{2\left(-10.0 \text{ m/s}^2\right)}$$

$$= +31.25 \text{ m}$$

Total distance is 18.75 + 31.25 = 50.0 m. It hits the barrier.

Textbook question 25. b.:

Reaction distance is 18.75 m, so the car must stop in 21.25 m (40.0 m − 18.75 m).

$$v_f^2 = v_i^2 + 2ad$$
$$v_i^2 = v_f^2 - 2ad$$
$$v_i^2 = 0^2 - 2\left(-10.0 \text{ m/s}^2\right)\left(21.25 \text{ m}\right)$$
$$v_i^2 = \sqrt{425 \text{ m}^2/s^2}$$
$$v_i = 20.6 \text{ m/s or } 74.2 \text{ km/h}$$
$$= 21 \text{ m/s or } 74 \text{ km/h}$$

The maximum speed cannot exceed 74 km/h.

Textbook question 28. a.:

Car	Truck
$\bar{a} = +6.0 \text{ m/s}^2$	$\bar{v} = +21 \text{ m/s (constant)}$
$\bar{v}_i = 0$	
$\bar{d} = \bar{v}_i t + \dfrac{1}{2}\bar{a}t^2$	$\bar{d} = \bar{v}t$

Since the distance and the time will be equal for both the car and the truck when the car catches up, their equations can equal each other.

$$\bar{v}_i t + \frac{1}{2}\bar{a}t^2 = \bar{v}t$$

$$\frac{1}{2}\bar{a}t^2 = \bar{v}t \quad (\text{Since } \bar{v}_i = 0 \text{ m/s}, \bar{v}_i t = 0.)$$

You do not have a value for time, so solve for t first.

$$\frac{1}{2}\bar{a}t^2 = \bar{v}t$$
$$\frac{1}{2}\bar{a}t^{\cancel{2}^1} = \bar{v}\cancel{t}^1$$
$$t = \frac{2\bar{v}}{\bar{a}}$$
$$t = \frac{2(21 \text{ m/s})}{6.0 \text{ m/s}^2}$$
$$t = 7.0 \text{ s}$$

Now that you have a value for t, substitute it back into the original displacement equations to find a value for $\vec{d}$.

Car

$$\vec{d} = \frac{1}{2}\vec{a}t^2$$
$$= \frac{1}{2}\left(6.0 \text{ m/s}^2\right)\left(7.0 \text{ s}\right)^2$$
$$= 147 \text{ m}$$
$$= 1.5 \times 10^2 \text{ m}$$

Truck

$$\vec{d} = \vec{v}t$$
$$= \left(21 \text{ m/s}\right)\left(7.0 \text{ s}\right)$$
$$= 147 \text{ m}$$
$$= 1.5 \times 10^2 \text{ m}$$

The car will travel 1.5×10^2 m before it catches up to the truck.

Textbook question 28. b.:

$$\vec{v}_i = 0$$
$$\vec{v}_f = ?$$
$$\vec{a} = 6.0 \text{ m/s}^2$$
$$t = 7.0 \text{ s}$$

$$\vec{v}_f = \vec{v}_i + \vec{a}t$$
$$= 0 + \left(+6.0 \text{ m/s}^2\right)\left(7.0 \text{ s}\right)$$
$$= 42 \text{ m/s}$$

The car is travelling at 42 m/s when it catches up to the truck.

Physics 20

Student Module Booklet
Module 1

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